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International Research Trends related to Indoor Environmental Quality and Energy Conservation in buildings

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International Research Trends related to Indoor Environmental Quality and Energy Conservation in buildings.

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INTRODUCTION

All over the world there is today a lot of focus on energy conservation in buildings, possible use of renewable energy sources and search for new energy sources. It is very important to realize that the reason for building buildings and install heating, cooling and ventilation systems is to provide a healthy and comfortable indoor environment that does not impair the productivity of the occupants. Therefore the research trends have been to find energy efficient measures and technologies that will provide an acceptable indoor environment.

In many cases it is possible to improve the indoor environment and at the same time reduce energy consumption. An example is the increase in better insulation of windows and external walls that result in a more uniform indoor thermal environment with less risk of radiant asymmetry, risk of draught and vertical air temperature differences. Unfortunately the tighter buildings have often resulted in too low ventilation rates in many residential buildings. The energy efficient measures could be to look at possible extension of the normally accepted comfort criteria in buildings. The field studies on people's adaptation and expectation in relation to the acceptable room temperature during summer in natural ventilated buildings using window openings is an example of a new concept for reducing the need for air conditioning under certain conditions. Other measures that will be discussed in the paper are the use of increased air velocities in rooms to compensate for increased room temperatures instead of applying mechanical cooling. Recent studies have also found that it is quite acceptable to provide a drifting temperature during the day, which can result in reduction of energy consumption and peak loads.

Finally many research projects are studying new technologies like personalized HVAC systems, use of air cleaning technologies to substitute for fresh outside air, use of low emitting building materials, low temperature heating-high temperature cooling systems and improved control systems. These technologies will in most cases provide an acceptable indoor environment with reduced energy consumption.

METHODS

This part of the paper will deal with some of the measures and technologies which that has been studied to reduce energy consumption and increase the indoor environmental quality or not decrease the quality. When talking about the indoor environmental quality the factors of importance is the thermal climate, indoor air quality, noise-acoustic and lighting conditions. The present research trends are increasingly focusing on field studies in real buildings and the use of detailed dynamic computer simulations of buildings with different technologies.

RESULTS

Thermal environment

The criteria for the thermal environment in buildings without mechanical cooling may be specified using a method differently from those with mechanical cooling during the warm season due to the different expectations of the building occupants and their adaptation to warmer conditions. The level of adaptation and expectation is strongly related to outdoor climatic conditions. In summer most naturally ventilated buildings are free-running so there is no mechanical cooling system to dimension and the criteria for the categories are based on indoor temperature. Summer temperatures are mainly used to design for the provision of passive thermal controls (e.g. solar shading, thermal capacity of building, design, orientation and opening of windows etc) to avoid over heating of the building.

The research trends are here to get more knowledge for which type of buildings this approach and what is the best way of representing the outdoor temperature. ASHRAE 55 use a monthly average outdoor temperature and EN15251 uses a running weekly average outside temperature.

For a temperate climate like Copenhagen the EN15251 shows more fluctuations (figure 1) because of the weekly average compared to the monthly. Also the max temperature is a little higher i.e. 27^{o}C. Except for the maximum week the adapted approach for natural ventilated buildings requires lower temperatures than ASHRAE 55 and EN15251 requires for mechanical cooled buildings. This does not seem logical and may require some further studies.

Recent studies on the acceptance of temperature drifts during a working day show that no discomfort is introduced by starting at the cooled end of the comfort range in summer and end the day at the upper end. This open up for the use of energy storage in the building to save energy for cooling and reduce peak loads.

To reduce the need for air conditioning recent studies have looked at the possibility of compensating for high room temperatures by increased air velocities. This has resulted in a new diagram (Figure 2) in ASHRAE 55, where higher air velocities are accepted.

Studies from China show that the use of increased air velocities with a fluctuation pattern similar to natural wind is more acceptable to people.

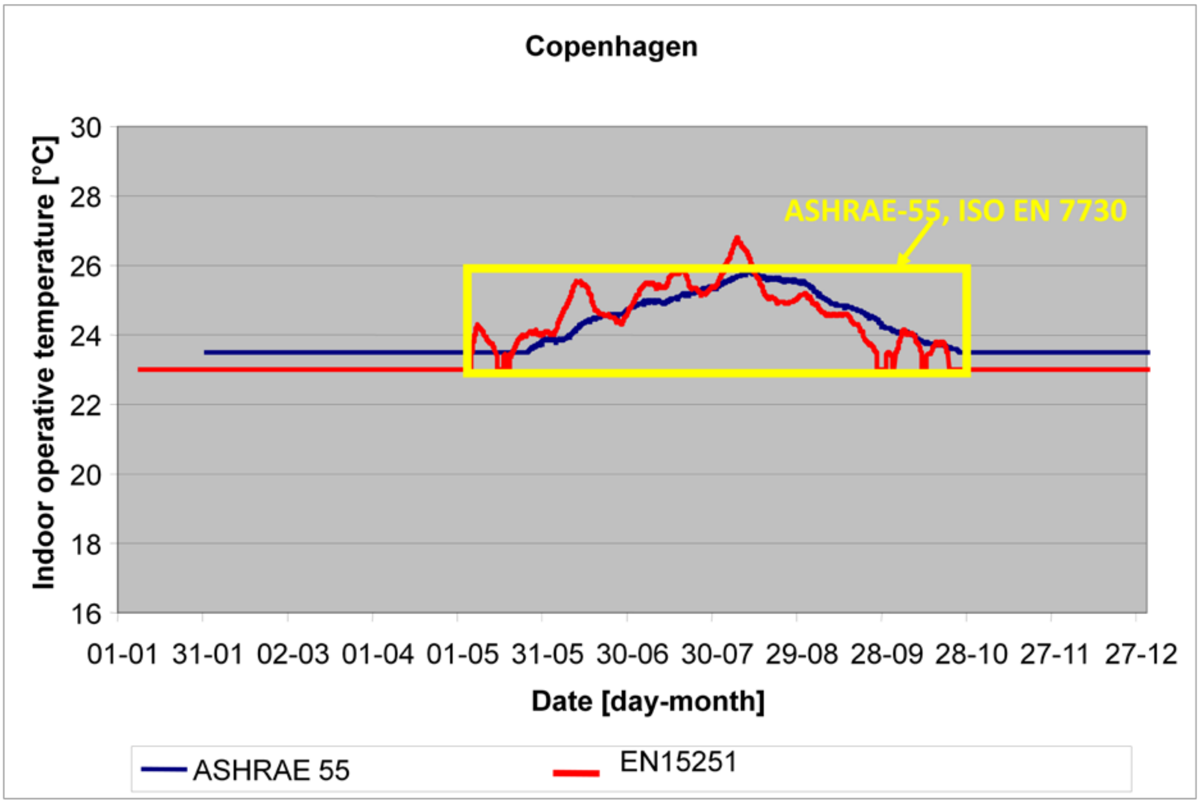


Figure 1 Upper limit for the maximum temperature during summer based on the adapted approach in ASHRAE 55 and EN15251 compared with the requirements for mechanical cooled buildings. Weather data for Copenhagen, Denmark is used.

All these studies are looking at the acceptance of increasing the upper room temperature limit in summer to save energy for space cooling. There is however a need to look at any effect on people's productivity at these high temperatures combined with increased air velocity.

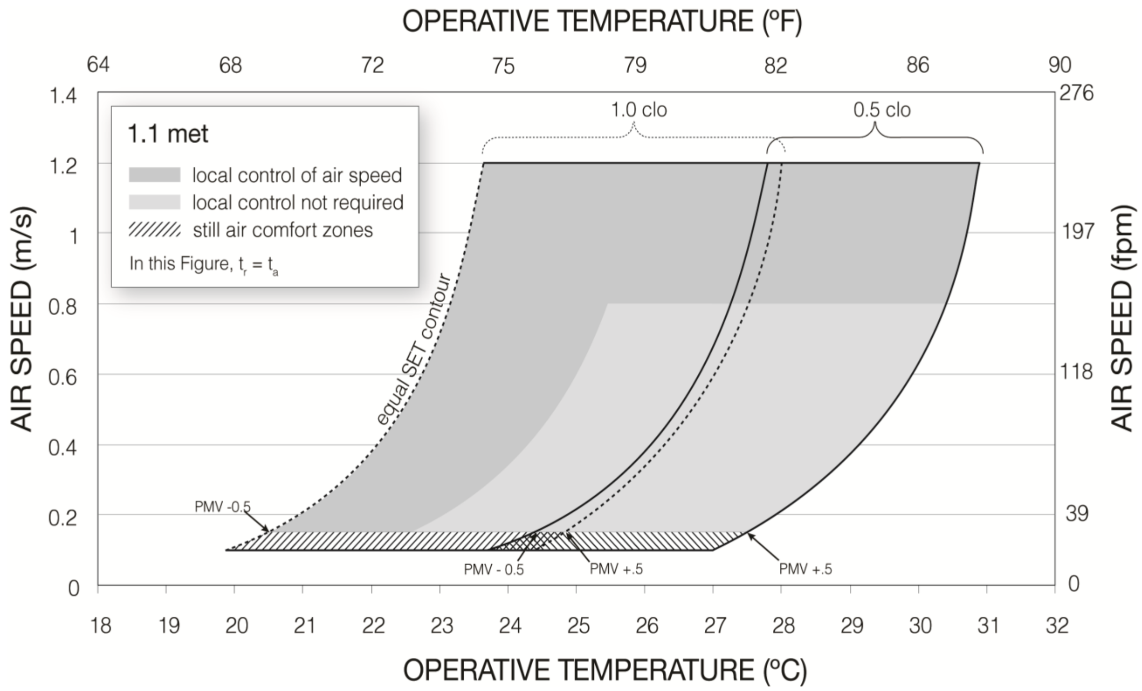


Figure 2 Acceptable ranges of operative temperature and air speeds for the comfort zone shown.

Indoor air quality

Air purification is not taken into account at all in EN15251, while ASHRAE 62.1 by using the analytical procedure can allow some credits for air cleaning. There is an increased interest in the development of air purification equipment. This may be an acceptable way of reducing the amount of outside air, saving energy and still having an acceptable indoor air quality. However, better test methods for air cleaners are required, because at present the test is usually based on chemical measurements and the resulting effect on odour or perceived air quality is not taken into account. It is also very important to specify which kind of "pollutants" should be used when testing. Some air purification systems may work well on VOC's (emission from materials) but have zero or even a negative effect if the source is people (bio effluents).

The requirement to indoor air quality is often given as requirement to the ventilation rate. The ventilation rates specified in standards (ASHRAE 62.1, EN15251) are the required rates at breathing level in the occupied zone. The required ventilation rate at the room supply diffusers are calculated as:

$$\text{Total ventilation rate V} \quad = V_{bz} / \varepsilon_v$$

Where:

V_{bz} = *breathing zone ventilation*

ε_v = Ventilation effectiveness

In most cases it is assumed that the pollutant emission is uniform, so the ventilation effectiveness is the same as the air distribution effectiveness. The air distribution efficiency is a function of the position and type of supply and return grills, and depends on the difference between supply and room temperature and on the total amount of airflow through the supply grill. The air distribution effectiveness can be calculated numerically or measured experimentally. Typical examples of ventilation effectiveness/air distribution effectiveness are shown in Figure 3.

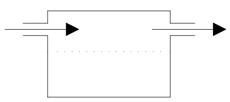
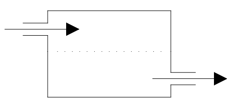
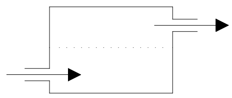
Mixing ventilation		Mixing ventilation		Displacement ventilation		Personalized ventilation	
							
T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T inhal °C	Vent. effect. -	T supply - T room °C	Vent. effect. -
< 0 0 - 2 2 - 5 > 5	0,9 - 1,0 0,9 0,8 0,4 - 0,7	< -5 -5 - 0 > 0	0,9 0,9 - 1,0 1	<0 0-2 >2	1,2 - 1,4 0,7 - 0,9 0,2 - 0,7	-6 -3 0	1,2 - 2,2 1,3 - 2,3 1,6 - 3,5

Figure 3. Typical examples of ventilation/air distribution effectiveness

To use ventilation effectiveness can be one way of taking into account personalized ventilation; but we need also to look at issues like acceptance of higher air velocities and less strict requirements to the general environment if the person is equipped with a personal system.

The most efficient way of reducing energy consumption for ventilation and increase the indoor environmental quality is reducing the sources of emissions in buildings. There is an urgent need for better certification and labeling of the materials used in buildings and the ventilation standards must include methods that favor the manufacturers of “good” (low polluting) materials. A start has been made by defining three types of buildings in EN15251, but the method for evaluating to which type an existing or projected building should belong is not good enough.

Who should we ventilate for? For people just entering the room (un-adapted) or for people already occupying a room (adapted)? Here the philosophy adopted by ASHRAE 62.1 and EN15251 differs. But should it really be one or the other? In a conference room, auditorium or lecture room most people enter at the same time. It then takes some time before the odour level has reached an unacceptable level and meanwhile people adapt. In this case it may be appropriate to require a ventilation rate based on adapted persons. There may be other spaces where you would design for un-adapted people, e.g. in a first class restaurant, offices, and department stores. It seems logical that more differentiated criteria could be used.

Even if we today have standards and guidelines for estimating the required minimum ventilation rate, they are far from being complete. The goal is of course to be able to calculate the required ventilation rate as straightforwardly as in cooling load calculations. We need to know the requirements for acceptable indoor air quality based on health, comfort and performance and we need to know the emission rates from all the sources. Unfortunately, this is not as easy as in cooling load calculations, where room and outside temperature (^{o}C), energy emission (watts), heat storage, solar radiation (watts) are all evaluated with similar units and all affect the same parameter of the human body (heat balance). For indoor air quality, we have thousand of substances that are emitted from people, furnishing, systems, from outside etc., each of which may affect one or more organs of the body.

Lighting

The decrease in energy use for lighting can be attributed to the increasing use of low energy bulb and the architects increasing use of day lighting. The increased use of day lighting may however result in higher internal loads due to diffuse or direct solar radiation.

Noise-Acoustic

Also for noise energy saving measures as better insulation of facades has decreased the risk of disturbing outside noise. On the other hand increased use of water based radiant heated and cooled ceiling systems in commercial buildings reduces the possibility of using the ceiling as absorption surface for acoustical reasons.

Performance

The effects of indoor environmental quality on performance became an issue only in the last decade, as a result of extensive research and an understanding of the strong connections between factors such as ventilation, air-conditioning, indoor pollutants and adverse effects on health and comfort. The complexity of a real environment makes it very difficult to evaluate the impact of a single parameter on human performance, mostly because many of them are present at the same time and as a consequence, act together on each individual. In addition, worker motivation affects the relationship between performance and environmental conditions (e.g. highly motivated workers are less likely to have reduced performance in an unfavourable environment; however they may become more tired and that may also affect performance). Based on the current knowledge regarding IAQ and performance of human work it seems that it is worth investing fundamental resources to improve the quality of the indoor environment.

CONCLUSIONS

Several research studies are looking for possible extension of the thermal comfort zone upwards during summer to reduce the need for air conditioning. The use of the adaptive model, increased air velocity and personal conditioning systems makes people accept higher room temperatures during summer; but will the elevated temperatures decrease the performance of the occupants. Still a need to study in which type of buildings these concepts is recommended.

Recent research has resulted in improved personalized ventilation and conditioning systems, which can improve the indoor environment at a work place in an energy efficient way.

The results of research on improved air distribution in spaces demand control ventilation and the use of air purification will be future technologies that reduce energy consumption and may improve comfort.

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