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International Energy Agency
Energy Conservation in Buildings
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Air Infiltration and Ventilation Centre

Ceiling Fans

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Figure 1 : Examples of ceiling fans

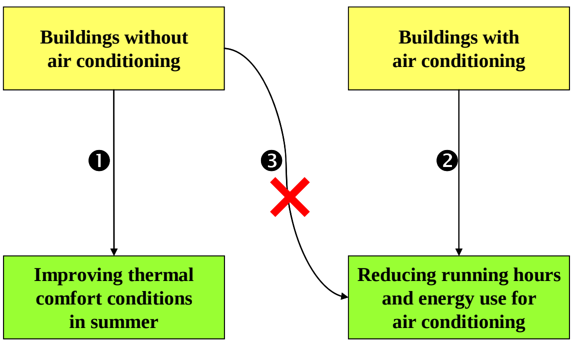
1 Introduction

Ceiling fans are one of the more credible techniques to decrease the energy consumption for air conditioning and improve comfort. Historically, ceiling fans have first emerged in hot humid climates and have become more and more popular in certain parts of the world from the early decades of the last century.

Examples of ceiling fans are given in figure 1.

Ceiling fans when in use can extend the **summer comfort** zone, i.e. improving the thermal comfort at higher temperatures (e.g. up to 29 °C). As such, they can have several substantial advantages:

1. In non-air conditioned buildings, ceiling fans can substantially extent the periods of acceptable thermal comfort conditions resulting in better thermal comfort and improved productivity;
2. in air conditioned buildings, they can reduce the use of air conditioning (in hours of operation and in energy use) by setting the room thermostat at a higher temperature.
3. Ceiling fans can avoid the need to install active cooling systems



Ceiling fans can also improve the energy efficiency during the **heating season** by reducing vertical stratification: the warm air in the top of the rooms is then driven to the bottom parts of the room. This typically requires to change the sense of rotation of the blades.

Studies, mainly performed in USA, have shown that there are in air conditioned buildings important energy gains associated with the use of ceiling fans. However, monitoring of a high number of buildings has shown that energy gains are only possible if associated with an increase of the set point temperature.

The present paper aims to present the main advantages of ceiling fans, the existing knowledge on the impact of ceiling fans on comfort as well as the knowledge on the expected energy gains. Finally, some recommendations on the proper use of the fans are given

2 Use of Ceiling Fans

Ceiling fans have extensively penetrated in the US and Asian market, while penetration in the European market is almost negligible. According to a study by Ecos Consulting and the USA Natural Resources Defence Council, (2001), two of every three homes in the USA have at least one ceiling fan, and - on average - each fan consumes about 130 kWh per year. In total there are almost 193 million ceiling fans in US.

According to DOE, (2002), in 2001, there were 107 million residential households in the United States; 70 million of these households or 65 percent had ceiling fans. This was a 14 percent increase over the 61 million households with ceiling fans that was reported in the1997 RECS. There were a total of 193 million ceiling fans in all U.S. households in 2001. This means an average of 2.8 ceiling fans per households with at least 1 fan in the house and 1.8 ceiling fans for all USA households (Table 1).

3 Ceiling and Comfort : information from field studies

Ceiling fans when used can increase the interior air velocity and, therefore, can improve thermal comfort (Chand, 1973, Chandra 1985). According to Omer (2006) this effect appears to be due to a peak response of human thermoreceptors just beneath the skin.

Rohles et al. (1983) and Scheatzle et al. (1989) have shown that ceiling fans can extend the comfort zone outside the typical ASHRAE comfort zone (Figure 2). The experiments have been performed in K.S.U (Kansas State University) and have exposed 256 human subjects to air motion created by ceiling fans. In particular, it is found that at an air velocity of 1.02 m/s, thermal comfort may be achieved at

- 27.7 °C, for 73 % relative humidity,
- 29.6 °C for 50 % humidity and
- 31 °C for 39 % relative humidity.

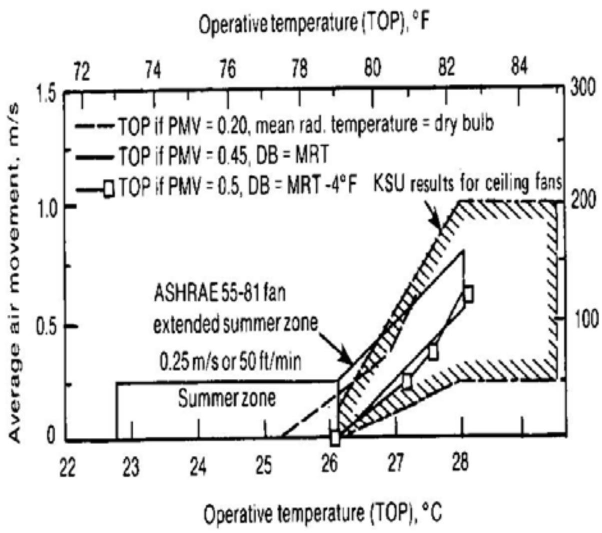


Figure 2 : Extended comfort zone for ceiling fans

Table 1 : Household Characteristics by Ceiling Fans in US.

Housing Unit and Household Characteristics	Total Households (million)	Households With Fans (million)	Percent of Households With Fans	Number of Ceiling Fans (million)	Average Number of Fans: Per Households With Fans	Average Number of Fans: Per Total Households	RSE Row Factors
RSE Column Factor:	1.0	1.2	0.7	1.5	0.7	1.1	
Percentage of Rooms Air-Conditioned							
100%	58.8	42.6	72.5	131.2	3.1	2.2	2.3
50% to 99%	12.1	8.6	71.2	22.5	2.6	1.9	4.8
25% to 49%	6.4	4.0	62.2	8.9	2.2	1.4	6.3
1% to 24%	3.5	2.1	59.8	5.8	2.8	1.7	8.8

Clark (1989) concludes that:

- Ceiling fans create a highly turbulent and variable quality air motion that contributes to more comfortable effects than a uniform air motion;
- Air speeds around 1.0 m/s are not perceived as annoying or drafty. Moreover, the 1.0 m/s air speed was not found to be the maximum allowed speed;
- When ceiling fans are used, an air speed of 1.0 m/s at 29 °C can be equivalent to 24 °C without the ceiling fan.

According to EN 15251 'Under 'summer comfort conditions' (indoor operative temperatures > 25 ºC) increased air velocity may be used to compensate for increased air temperatures. Where there are fans (that can be controlled directly by occupants) or other means for personal air speed adjustment (e.g. Personal Ventilation systems) the upper limits presented can be increased by a few degrees. The exact temperature correction depends upon the air speed that is generated by the fan and can be derived from Figure 3. This method can also be used to overcome excessive temperatures in mechanically controlled buildings if the local method for controlling air movement (fan etc) is available'

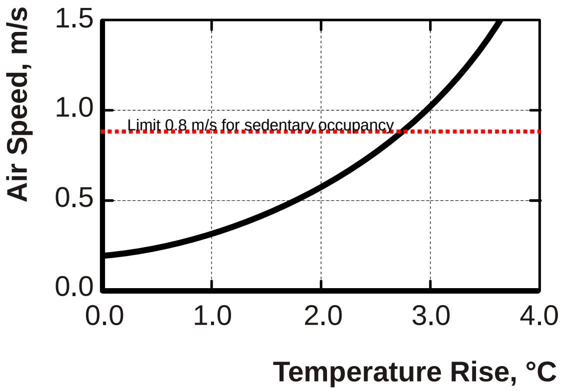


Figure 3: Air speed required to offset increased temperature (ASHRAE Standard 55, EN ISO 7730). The air speed increases by the amount necessary to maintain the same total heat transfer from the skin. Acceptance of the increased air speed will require occupant control of device creating the local air speed

Regarding the maximum air speed, experiments performed by McIntyre (1976) concluded that 2 m/s is the upper limit of acceptable air speed.

Information on the velocity distribution in a room equipped with ceiling fans is given by Vieira (1983), Clark et al. (1983), Chandra et al. (1983) and Bailor (1986). The air motion created by a ceiling fan is a toroid with a high velocity downward core in the stream directly under the ceiling fan. At a 1 m height, there is a medium velocity region near the walls and across the ceiling. In the region between, the velocity is quite low.

The air speed generated by ceiling fans and the created comfort conditions have been studied by Mallick, (1996). The air movements generated under various speeds in a room are given in Table 2. It was concluded that comfort temperatures increase with air movement but only above a minimum air speed:

- For speeds up to 0.15 m/s, comfort does not improve when increasing the air velocity.
- For speeds of 0.3 m/s, the upper and lower limits of the conventional comfort zone have been increased up to 2.4 and 2.2 °C respectively.
- For a higher speed of 0.45 m/s, the change in both limits is less than 1 °C. The comfort zone that corresponds to the various air speeds generated by ceiling fans is given in Table 3

Thus, ceiling fans at middle to high air speeds may substantially contribute to improve the comfort conditions in buildings.

4 Ceiling Fans and Energy Consumption

Of course, ceiling fans consume energy. The power of the motor is typically between 10 and 100 W.

However, the use of ceiling fans can avoid the need to install air conditioners or can reduce the running hours of air conditioners and their consumption. Ceiling fans can save energy at the condition that the users raise the settings of the air conditioning thermostats.

It is evident that ceiling fans use less energy than air conditioners as motors use between 10-100 Watts, while room air conditioners consume 600 to 3000 Watts. Many studies have been performed mainly in US to identify possible energy gains.

Table 2 : Air movement by various speeds settings of a ceiling fan, (Mallick, 1996)

Fan speed setting	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Average
Slow (m/s)	0.17	0.17	0.12	0.14	0.14	0.16	0.15
Medium (m/s)	0.3	0.29	0.31	0.28	0.3	0.32	0.3
Fast (m/s)	0.54	0.39	0.42	0.5	0.42	0.43	0.45

Table 3 : Comfort temperatures for different air velocities, (Mallick, 1996)

Fan speed setting	Air movement (m/s)	Comfort range (°C)	Mean comfort temperature (°C)
None	0	24–33	28.9
Slow	0.15	24–33	29.5
Medium	0.3	26.4–35.2	30.9
Fast	0.45	27–35.8	31.6

Fairey et al. (1986) have shown that the use of ceiling or oscillating fans may contribute significantly to reduce the cooling load of buildings in Southern US if the thermostat settings are raised accordingly. As reported, energy savings of about 30 % are calculated for typical frame buildings in Orlando and Atlanta by increasing the thermostat setting from 25.6 C to 27.8 C. The energy savings may increase up 50 % for heavy mass buildings.

In the Florida climate, savings are roughly 14% for a 1.2 °C increase, according to the Florida Solar Energy Center. Although studies suggest a 1.2 – 3.4 °C increase in the thermostat set point, James et al. (1996) report that in 386 surveyed Florida households, they have not identified statistically valid differences in thermostat settings between houses using fans and those without them, although fans were used an average 13.4 hours per day.

5 New Advanced Design of Ceiling Fans

As it concerns the design of efficient ceiling fans, Schmidt and Patterson (2001) have designed a new high efficiency ceiling fan that can decrease the power consumption and therefore electricity charges by a factor between two and three. A very efficient ceiling fan with improved aerodynamics blades has been designed and tested by Parker et al. (1999). This ceiling fan presents a much higher air flow performance than existing fans and is using advanced control technology. It is characterised by a much higher air flow per input watt, about a 100% increase in airflow performance (m^3/h per Watt) in comparison to a conventional flat-bladed fan with the same motor, a better and more uniform distribution throughout the room achieved by steadily adjusting the pitch or degree of twist of the blade along the blade's length and a quiet operation (Figure 4).

Comparison tests against existing ceiling fans have shown a 40% increase in airflow (Figure 5).

Figure 4 : The Hampton Bay Gossamer Windward II ceiling fan

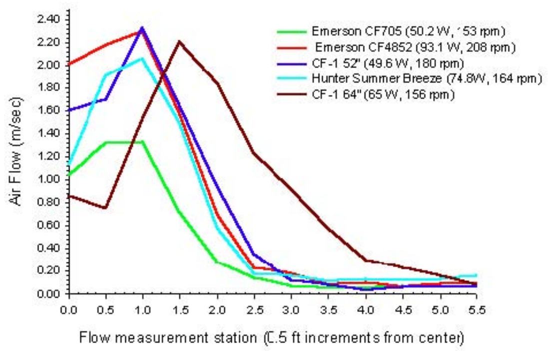


Figure 5 : Results of test of various ceiling fans, (Parker, 1999)

6 Some Recommendations

Chand (1973), in his pioneering work, has studied the air motion produced by a ceiling fan and has concluded to the following recommendations (Figure 6):

a) The minimum clearance between the fan blades and the ceiling should be about 30 cm;
b) The flow capacity of a fan to meet the requirement of a room with a longer dimension L metres should be equal to about 55 L m^3/min, while
c) the reduction of the ceiling height from 2.9 m to 2.6 m produces an increase in the air movement in the zone.

Regarding the operational mode, most of the ceiling fans come with a forward and a reverse setting:

- On "forward" mode, the fan blows the air down. So, when one stands under the fan, one feels a breeze.
- On "reverse" mode, the fan blows the air up, and someone that stands under the fan, is not feeling a direct breeze. Given that the warm air is near the ceiling, during the winter, the fan has to operate on "reverse" mode to circulate the warm air without blowing air down. A ceiling fan, running in reverse, gently mixes the air and helps move the warm air down. During the summer, on the other hand, the ceiling fan has to operate in "forward" mode to create a wind-chill effect as the air moves against the skin and cools the human body.

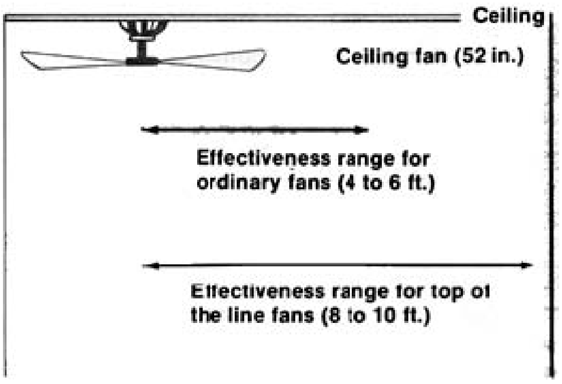


Figure 6 : Recommendations on the use of ceiling fans

7 Passive cooling

Ceiling fans can increase the market for passive cooling techniques, including intensive night ventilation.

During the last decade, passive cooling strategies based on night ventilation strategies (including hybrid ventilation) have received a lot of interest. In any climates, such techniques allow to substantially decrease the temperature of the building at night time. If combined with appropriate solar control and a minimisation of internal gains, the thermal comfort in many buildings can be substantially improved and, as such, reducing the need for installing active cooling.

In practice, one observes that during certain hot periods, the thermal comfort in buildings with passive cooling techniques might be critical. The use of ceiling fans can during such periods guarantee acceptable comfort conditions without the need of active cooling.

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The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote the understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in the design of new buildings and the improvement of the existing building stock.