**World Sustainable Built Environment Conference 2017 Hong Kong**
Transforming Our Built Environment through Innovation and Integration:
Putting Ideas into Action
5-7 June 2017

**Registration ID:** 2447

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# Khind HQ Office: Thermal Comfort at Elevated Air Speed in Tropical Climate

## ABSTRACT

The latest Ashrae 55 (2013) incorporated a thermal comfort compliance model for elevated air speed. This compliance model suggested that it is possible to increase operative temperature up to 30 Celsius with an elevated air speed of 0.8 m/s without local control of air speed by the occupants.

An office building in Shah Alam, Malaysia, was retrofitted to test the office occupants' acceptance of thermal comfort based on an elevated air speed. Ceiling fans with 3 operating speeds were installed and the temperature set point of the air-conditioning system was varied between cold to warm for each tested fan speed. The office staff have no knowledge of when the fan speed was increased or decreased. They also have no knowledge of when the air temperature was increased or decreased. The office staffs were encouraged to make complaint to a designated person whenever they felt that the environment is unacceptable for rectification to be made.

A numbers of temperature and humidity data logger are placed randomly at table height to capture the actual air temperature and humidity of the tested space. The study was conducted over 1-month period in late 2015 to 2016.

The result of this study indicates that the tested subjects made complaint on a number of personal discomfort issues at an elevated air speed in an office space that is beyond the conventional hot and cold sensation. The result indicates that the Ashrae 55 (2013) thermal comfort model for an elevated air speed has to be further refined to account for occupant's expectation of different space types.

*Keywords: Indoor Environmental Quality, Energy saving, Thermal Comfort*

## 1. INTRODUCTION

In a hot and humid climatic country such as Malaysia, air-conditioning is the primary energy use in office buildings. In Malaysia, air-conditioning contributes to approximately 50% of an office building total energy consumption, with lighting and plug load contributing to the rest [1]. Air-conditioning in office buildings are provided for the primary purpose of delivering thermal comfort to the office workers to ensure productivity.

Conventional method of delivering thermal comfort in Malaysian office buildings is to provide an air conditioning system to maintain indoor air temperature at 23□C, 50~60% relative humidity and an average air speed of 0.1 m/s or less.

Ashrae Standard 55 recently added a provision for thermal comfort at elevated air speed allowing building designers to predict the possible operative temperature to be provided at different air speed. This provision in Ashrae 55 is provided as a thermal comfort chart for evaluation of thermal comfort at air speed beyond 0.2 m/s.

An on-site assessment was carried out for an office building in Malaysia, to test the possibility of elevating the local air-speed up to 0.8 m/s. Ashrae 55 thermal comfort chart for elevated air speed, showed that an operative temperature up to 30□C was possible for an air speed of 0.8 m/s, instead of 25□C at 0.1 m/s air speed. This offer an opportunity improve energy efficiency in air-conditioned building by allowing a space to be operated at a higher operative/air temperature.

The on-site assessment methodology for thermal comfort at an elevated air speed and results of this study are presented in this paper.

## 2. ELEVATED AIR SPEED IN ASHRAE 55

Ashrae 55 (2013) standard on elevated air speed for thermal comfort is divided into two (2) categories; with occupant control; and without occupant control. With occupant control, there is no upper limit on the air speed provided; without occupant control, an upper limit of air speed was set at 0.8 m/s. It was also mentioned that these conditions are only valid for operative temperature above 25.5□C; indicating a potential for draft discomfort when the operative temperature is lower than 25.5□C.

At an air speed of 0.8 m/s, the Ashrae comfort chart predicted comfort conditions at operative temperature of ~26.9□C to ~30.2□C as presented in Figure 2; based on a summer clothing insulation value of 0.5 clo.

The potential to achieve thermal comfort at such operative temperature is significant for Malaysian climate because it would then be possible to use natural ventilation for comfort purpose with the exception hours of 11 am to 4 pm; as shown by Figure 1 of the outdoor air temperature in Malaysia. In addition, the air-conditioning energy consumption will be significantly reduced when it is operated at a higher temperature.

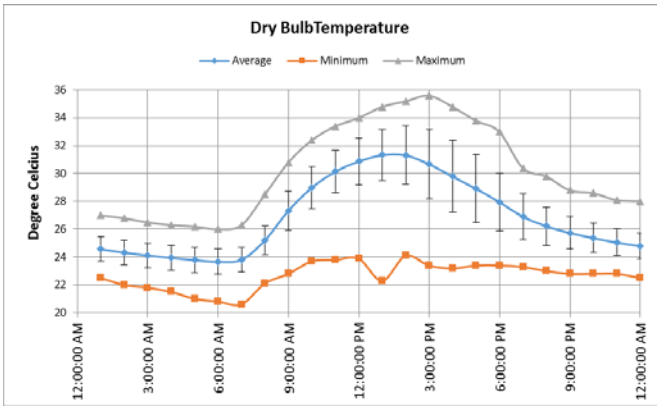

Figure 1: Typical Dry Bulb Temperature of Malaysia

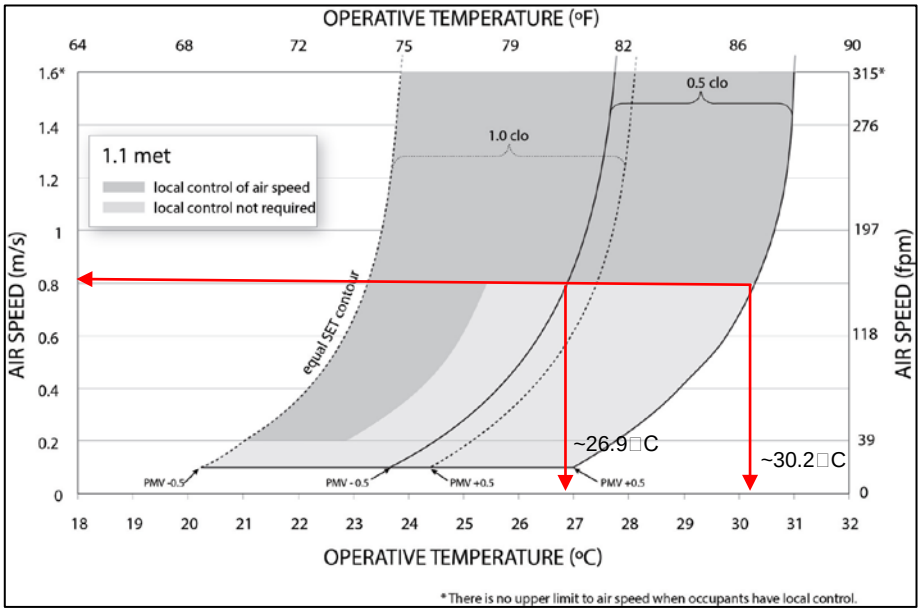


Figure 2: Thermal Comfort at Elevated Air Speed of 0.8 m/s

## 3. ASSESSMENT METHODOLOGY

The office building used for this assessment belongs to Khind Holding Berhad, in Shah Alam, Selangor, Malaysia. Khind Holding is one of the leading local manufacturer of household appliances in Malaysia. Two floors of their office building, with a total occupancy of 50 office staffs (mostly females) were selected for this assessment to be made. The assessment was made on existing office spaces with existing office staffs. The air-conditioning for these spaces are provided by direct expansion ceiling cassette unit and is used every working day. There was no complaint of thermal discomfort by the existing office staffs at these offices.

2 of the floors in this building were selected for this study to be made. Ceiling fans were installed at open plan office spaces to provide elevated air speed. These open plan office spaces are surrounded by smaller individual office spaces that acts as a buffer between the open plan office and the external wall as shown in the Figures 3 and 4. The tested spaces are almost completely surrounded by internal walls. The internal walls are made of lightweight plasterboard partition walls with low thermal mass. The external wall, internal wall, ceiling and floor were initially tested using a radiant temperature meter to measure the surface temperature of the walls. The results of the spot radiant temperature measurement made showed that the surface temperatures of the surrounding wall are consistently closed (less than 0.5□C differences) to the indoor air temperature throughout the day. With this result, it is then possible to conclude that the air temperature of the space is a close approximation of the operative temperature of the space.

A total of 45 numbers of ceiling fan was installed to provide elevated air speed in these spaces for the test to be conducted. The installed fans have 3 speeds; low, medium and high. Measurement of average air speed was made for each fan speed setting at various occupants' seated position (sitting position, shoulder level).

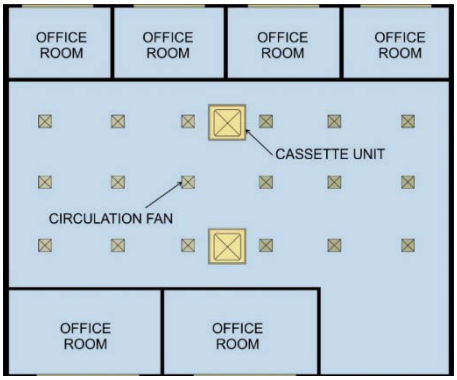


Figure 3: Purchasing and Marketing department layout (Level 1)

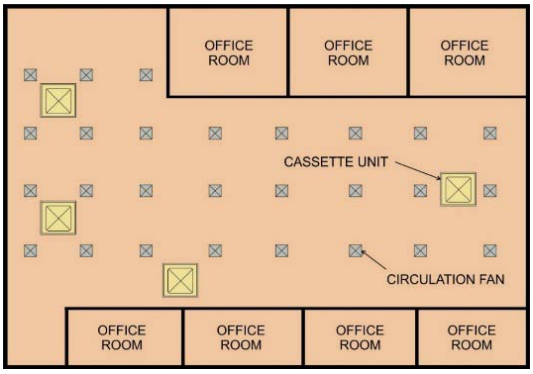


Figure 4: Finance department layout (Level 2)

Figure 5: Photo of ceiling fan and direct expansion cassette unit

Two data loggers for temperature and humidity were placed on each floor at working desk level. Care was taken that the data loggers have good ventilation, while avoiding any potential heat source coming from computer, monitor and etc.

Data logging and test were carried out from 30th November 2015 until 2nd January 2016 with a list of conditions to be tested. The office secretary was instructed to change the fan speed and air temperature of the ceiling cassette air-conditioning system daily. The secretary was given the discretion to select whichever conditions she wanted to test on any day, with the instruction to ensure that all the conditions are tested. Although the office staffs have knowledge that a thermal comfort assessment is on-going, they have no knowledge of the temperature set point changes that was made each day by the secretary.

The office staffs were encouraged to give their comments to the secretary whenever the environment become unacceptable for immediate rectification to be made. The nature of all complaints made were recorded with the time and date recorded. This allowed correlation to the fan-speed, measured air temperature and humidity at that point of time the complaint was made.

## 4. RESULTS

The measured average air speed at various fan speed set point is shown in Table 1 below.

Table 1: Measured Average Air Speed at Various Fan Speed Setting

| Fan Speed Setting | Measured Air Speed (m/s) |
|---|---|
| High | 0.9 – 1.1 |
| Medium | 0.6 – 0.8 |
| Low | 0.2 – 0.3 |
| Off | < 0.1 |

Test conducted at medium and high air speed was a failure from the beginning. At these air speeds, complaints were received to rectify the environmental comfort conditions within a couple of hours of operation at that condition. Complaints received were:

- Pieces of papers on the table were sent flying;
- Office occupants felt that their hair was being touched by the air, creating a disturbing environment; and
- Contact lens wearers felt that their eyes were drying up too quickly.

Test were only able to be conducted with the ceiling fan at low speed and at off speed. A summary of the results is tabled in Table 2 and 3 below.

Table 2: Thermal Comfort Results with Ceiling Fan Speed at Off

| Date | Ceiling Fan Speed | Air conditioning Set Point Temperature (°C) | Measured Temperature (°C) | Thermal Comfort Observations |
|---|---|---|---|---|
| 30/11/2015 | Off | 21°C | 25.2 | Cold |
| 4/12/2015 | Off | 22°C | 24.8 | Cold |
| 10/12/2015 | Off | 23°C | 25.3 | No complaint |
| 16/12/2015 | Off | 24°C | 25.7 | No complaint |
| 22/12/2015 | Off | 25°C | 26.4 | Warm |
| 28/01/2016 | Off | 25°C | 27.8 | Hot |

Table 3: Thermal Comfort Results with Ceiling Fan Speed at Low Speed

| Date | Ceiling Fan Speed | Air conditioning Set Point Temperature (°C) | Measured Temperature (°C) | Thermal Comfort Observations |
|---|---|---|---|---|
| 3/12/2015 | Low | 21°C | 24.5 | Cold |
| 9/12/2015 | Low | 22°C | 25.5 | No complaint |
| 15/12/2015 | Low | 23°C | 26.5 | No complaint |
| 21/12/2015 | Low | 24°C | 27 | Slightly Warm |
| 28/12/2015 | Low | 25°C | 28.5 | Warm |
| 2/01/2016 | Low | 26°C | 29.0 | Warm |

## 5. ANALYSIS

It was found from this on-site assessment that for an office environment, an elevated air speed higher than 0.6 m/s provided discomfort beyond conventional hot and cold sensation. Disturbance caused by high air speed such as loose papers taking off, drying of eyes (particularly for contact lens wearer), and feeling of individual's hair being touched by the air made the environment unacceptable to the office staffs, regardless of the indoor air temperature provided.

An elevated air speed up to 0.3 m/s was found to be acceptable by the tested occupants. Unfortunately, this assessment was unable to provide any data between the air speed of 0.3 m/s to 0.6 m/s, because the fan installed, was unable to provide

continuously variable fan speed. The next fan speed, medium, increases the average air speed to 0.6 m/s in the tested spaces.

Based on the low air speed set point of the fan; air speed range from 0.2~0.3 m/s; the highest air-temperature that was able to provide comfort to the tested occupants was 26.5□C. Increasing the air temperature beyond 26.5□C were found to be unacceptable by the tested occupants. However, it was also worth noting that the data also showed a day where the ceiling fan was off, and the measured average air temperature on that day was 25.7□C; and there was no compliant of discomfort at that day.

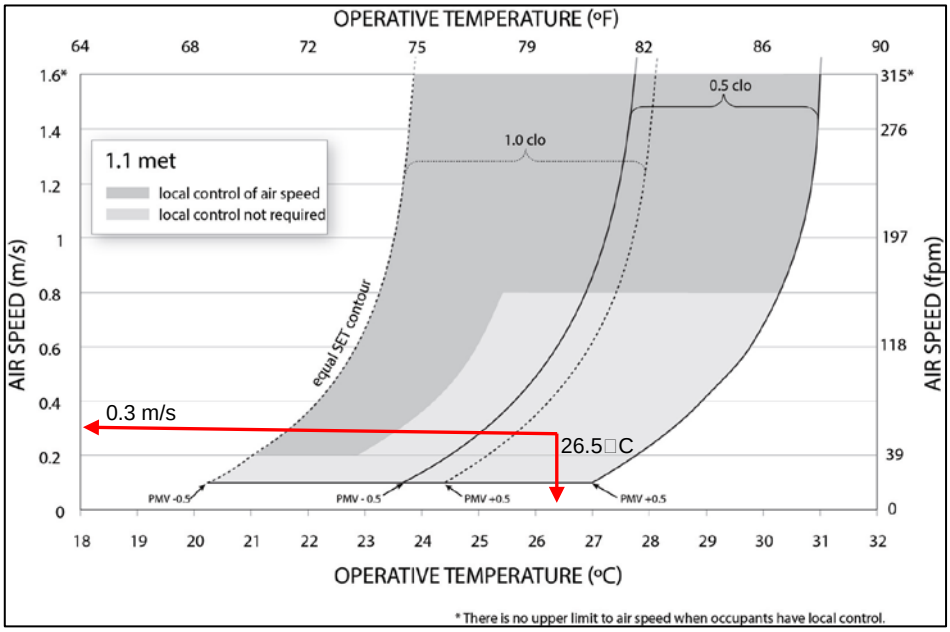


Figure 5-1: Accepted Thermal Comfort Condition at Elevated Air Speed of 0.3 m/s

Plotting the accepted conditions at an elevated air speed of 0.3 m/s and operative temperature of 26.5□C into the elevated air speed chart, Figure 5-1, showed that the accepted conditions is close to the middle between the lower and upper limit of operative temperature at that air speed for summer clothing value of 0.5 clo; i.e. at PMV ~0.0. This indicates that the thermal comfort sensation as predicted by the elevated air speed chart is accurate for an elevated air speed of 0.3 m/s.

Results from the data logger also showed that moisture content was kept between 10 g/kg to 12 g/kg during the entire duration of the test by the ceiling cassette fan coil unit. It was also observed that at lower room air temperature, the moisture content is typically lower (~10 g/kg); while at higher room air temperature, the moisture content is higher, at ~12 g/kg. This is an indication that a cassette unit fan coil unit automatically has the potential to reduce latent load removal when the air temperature was set higher.

The air-conditioning provided by the cassette fan coil unit kept the environment relative humidity around 55% regardless of the air temperature during the duration of the assessment. On days when the ceiling fans are set to a medium and high air speed, the evaporation rate of moisture increases, causing contact lens wearer to complaint of dry eyes.

This assessment exposed that people have different “expectation” of spaces. Casual observation of daily life in Malaysia, revealed that there are many low to medium cost food-courts/cafeterias/restaurants that served the office lunch crowd with only fan as thermal comfort means, i.e. without air-conditioning being provided. Spot measurement of air speed at some of these spaces showed air speed beyond 0.8 m/s. Moreover, there are often people in office attires that use these spaces for small business meeting between 2 to 3 persons, staying at these locations for hours, without any complaint of discomfort.

It can be concluded from this assessment that the environmental “expectation” of an office space is different from a low cost cafeteria. The same office workers that are comfortable with an elevated air speed environment in a cafeteria would find an elevated air speed beyond 0.6 m/s too disturbing for an office environment.

Finally, it is recommended for Ashrae 55 to conduct further research in to elevated air speed scenario to provide further clarity on this subject and perhaps to refine the acceptable limit of comfort based on the expectation for each space type.

## 6. SUMMARY

An assessment was made to test the possibility of implementing an elevated air speed environment for an office space as per the standard provided by Ashrae 55 (2013). An increase air speed up to 0.8 m/s without personal control by the occupants, is allowed by Ashrae 55 (2013). The standard showed that at an elevated air speed of 0.8 m/s, the operative temperature can be increased to 30□C while providing thermal comfort to the occupants.

The results from this assessment showed that Ashrae 55 (2013) thermal comfort conditions for an elevated air speed cannot be implemented blindly for an office environment in Malaysia. The result from this study showed that a known acceptable elevated air speed limit for the tested occupants in an office space is at 0.3 m/s. While an elevated air speed beyond 0.6 m/s was deemed unacceptable by the tested occupants. Personal discomfort beyond the sensation of hot and cold such as dry eyes, feeling of hair being touched by the air and loose paper flying of the table are the reasons provided for the condition to be unacceptable for an office space. Unfortunately, this assessment was not able to yield any data for air speed between 0.3 m/s and 0.6 m/s as the installed equipment is not capable of providing these air speeds.

At the air speed of 0.3 m/s, the accepted air temperature by the tested occupants matches with Ashrae 55 (2013) elevated air speed chart of operative temperature at middle point between the lower and upper limit. I.e. at PMV of 0.0; for summer clothing value of 0.5 clo.

This assessment exposed that the people have different “expectation” of spaces, especially with respect to an elevated air speed. While it is acceptable to have high elevated air speed beyond 0.6 m/s for some spaces, the same people would find it unacceptable for an office environment to have such high elevated air speed.

Finally, it is recommended that Ashrae should refine its standards on thermal comfort based on elevated air speed, addressing the various “expectation” of different space types.

## REFERENCES

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[3] Ashrae Standard 55-2013, Thermal Environmental Conditions for Human Occupancy, Atlanta, GA.