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Review of Inside Design Conditions in Air Conditioned Spaces

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There is a need to review the comfort conditions being maintained in air conditioned spaces, specifically used for comfort. In India, we have been following conditions as specified in ASHRAE Handbooks or as specified by consultants / users. In the last decade or so, the dry bulb temperature specified is lower than what was specified earlier. Considering the need for energy conservation, it is important to review the same and establish conditions suited to tropical Indian weather.

Air conditioning systems were designed, in India, about four decades ago, with inside conditions of 78°F (25.5°C) and 55% rh. Today they are being designed with inside conditions of 75°F (23.9°C) and 60% rh. Many times the systems are designed with even lower dry bulb temperatures of 21–22°C. Most often the user finds it uncomfortable at these lower temperatures, especially where occupancy is for a long duration.

Inside conditions are being generally adopted from Carrier Handbook or ASHRAE Handbook.

The ambient conditions in India, during summer months, vary between 35–45°C. When you move in and out of spaces at 22–25°C to outside at 35–45°C, you are going to

face a temperature difference of 13–23°C. This is much higher than the acceptable range of 8–12°C.

The purpose of this article is not to suggest any new conditions, but to bring to the notice of designers and users a need to review and establish conditions in a logical manner to suit Indian ambient conditions.

This view point received a favourable support during the International Conference "ACRECONF 2003", where a quick survey was done among its delegates in the conference hall of the Hyatt Regency, New Delhi. The results of the survey are given at the end of the article.

Thermal Comfort

The principal purpose of heating, ventilating and air conditioning systems is to provide for human thermal comfort. *Thermal comfort is that condition of mind that expresses satisfaction with the thermal environment*. In general, comfort occurs when body temperatures are held within narrow ranges, skin moisture is low and the physiological effort of regulation is minimized.

Comfort also includes behavioral actions initiated by the conscious mind and guided by thermal and moisture sensations to reduce discomfort. For example, altering clothing, altering activity, changing posture or location, changing thermostat setting, opening/closing windows, complaining or leaving the space are some of the possible behavioral actions to reduce discomfort.

Though regional climate conditions, living conditions and culture differ widely throughout the world, it is reported by some researchers that the preferred temperature that people choose for comfort under the same conditions of clothing, activity, humidity and air movement are similar.

Other researchers are of the opinion that a single value of indoor temperature, irrespective of climate is not right. Their research suggests that a more responsive standard can be determined using a field survey technique. (*Thermal Comfort in Pakistan* – Fergus Nicol and others – July 1994)[3].

Occupants of non air conditioned spaces will have a different perception of “comfort” than occupants of air conditioned spaces. It is felt that comfort conditions in air conditioned spaces for Indians need not be the same as that established by laboratory techniques used in America or European countries.

Methods of Determining Comfort Temperature

There are basically two methods of determining comfort conditions:

1. Laboratory
2. Field study

a) Laboratory method. Comfort conditions are based on experiments in climate chambers and on the science of thermodynamics and physiology. This depends on clothing and activity of the occupants. A single comfort temperature is established. ASHRAE Standards are based on this method.

Several indices have been classified to evaluate “comfort”. These are:

- **Direct indices**
  - Dry-bulb Temperature
  - Wet-bulb Temperature
  - Dew Point Temperature
  - Relative Humidity
  - Air Movement
- **Rationally derived indices**
  - Mean Radian Temperature
  - Operative Temperature
  - Heat Stress
  - Thermal Stress
- **Empirical equations**
  - Effective Temperature
  - Standard Effective Temperature
  - Equitorial Comfort

Equations have been developed to evaluate comfort levels incorporating some of the measured values of the above parameters during laboratory tests. We are not getting into the details of these at this stage.

b) Field study (adaptive process). Here the subjects under study are monitored in their normal surroundings with all the variability of the physical, cultural and social environment. By this method it is established that comfort conditions can be varied depending on the ambient weather.

Fergus Nicol [3], in his survey, has given an empirical equation for evaluating indoor comfort temperature for the sizing of heating and cooling plant as:

$T_c = 17.0 + 0.38\ T_o$

T_o = the mean of monthly maximum and minimum temperatures.

From this, for Delhi, T_c for the month of June works out to:

17+.38¥31.87 =29.11°C. (T_o for Delhi in June is 31.87°C)

This means that in Delhi one can feel comfortable at a temperature of 29°C in the month of June.

For Mumbai Tc for month of May works out to:

17+.38¥30.10 =28.44°C. (T_o for Mumbai in May is 30.10°C)

This means that in Delhi one can feel comfortable at a temperature of 29°C in month of June and in Mumbai the temperature is 28.44°C.

In a study done in Bangkok, Thailand by John N Busch[4] it has been reported:
"The upper bound of acceptable effective temperature, defined identically to the ASHRAE Standard 55-81 (Comfort Standard), is 28°C (82.4°F) in the AC building and 31°C (87.8°F) in NV (Naturally Ventilated) building, both of which are significantly higher than the comfort standard value of 26.1°C (79.0°F). Translating this finding into practice would result in abundant saving in building sector (energy consumption)."

Factors Affecting Comfort

The temperature, air speed, humidity, activity and clothing are primary factors that influence the comfort conditions. There are secondary factors such as day-to-day variation, age, adaptation, gender (men /women), seasonal and circadian rhythms.

Studies in India

There is hardly any work done in India on establishing the comfort conditions for air conditioned or non air conditioned buildings. The only reference is that of work done by Sharma and Ali[5], in which they have proposed an empirically based Tropical Summer Index.

Indian climate has been classified into 6 zones:

- Hot & Dry
- Warm & Humid
- Moderate
- Cold & Cloudy

• Cold & Sunny

• Composite

The residents of each zone may have a different perception of comfort. To design the indoor conditions, identical for all the zones, does not seem logical

Procedure of Survey

1. Room conditions DBT and RH are recorded separately.
2. Reaction of participants are recorded by the participants in the survey form.
3. These reactions have been compiled, analyzed and results formulated.
4. The preliminary findings of the survey are shown on the next page.

If the thermal comfort in a workplace is not perfect, how far from perfect is it? Within what limits should we maintain temperature and humidity to enable reasonable thermal comfort? To answer these questions, PMV (Predicted Mean Vote) index has been developed. This predicts the mean value of the subjective ratings of a group of people in a given environment.

PMV scale is a seven-point thermal sensation scale ranging from –3 (cold) to +3 (hot), where 0 represents the thermally neutral sensation.

Even when the PMV index is 0, there will still be some individuals who are dissatisfied with the temperature level, regardless of the fact that they are all dressed similarly and have the same level of activity.

To predict how many people are dissatisfied in a given thermal environment, the PPD index (Predicted Percentage of Dissatisfied) has been introduced. In the PPD index people who vote –3, –2, +2, +3 on the PMV scale are regarded as thermally dissatisfied.

Since the equations are complicated, they are not discussed here.

Results

The survey was conducted among 200 participants and 126 votes were received. The delegates were asked to fill a form and though the form asked many details about dress, practically every one was dressed in summer clothes, i.e., shirt, pant, vests and shoes. A few ladies were wearing sari / salwar-kameez. All the delegates were sitting. The temperature in the hall varied between 21–25°C and 55% rh approximately.

The table below has been prepared for PMV and PPD at different room temperatures (21–27°C) and relative humidity (50–60%). The values have been found by using

equations.

PMV (Predicted Mean Vote) and PPD (Predicted Percent of Dissatisfied)

PMV Cold –0.5< PMV >0.5 Warm

PPD <10 % Acceptable

Clothes = 0.7 – Shirt, Pant, Vest, Shoes.

Activity = 1.0 – Sitting, Writing.

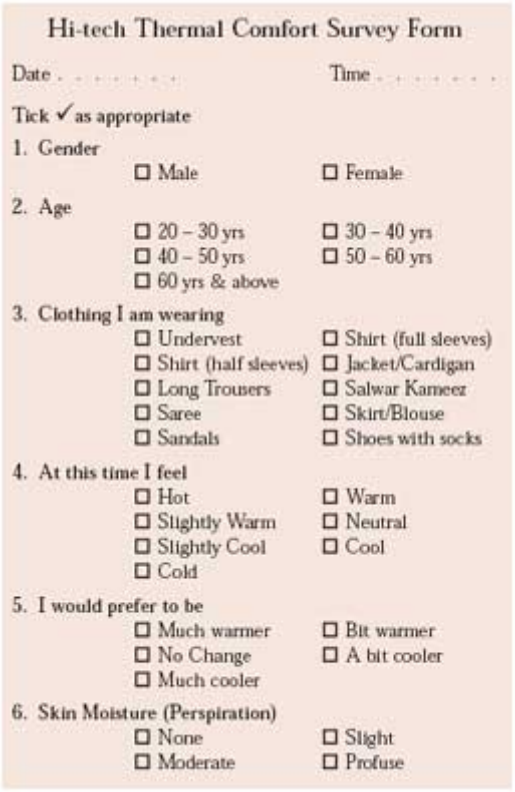
DB °C	RH %	PMV	PPD	Remark / Design
27	55	0.5	10.8	BAD
27	50	0.5	9.8	GOOD
26	55	0.2	5.6	GOOD
26	50	0.1	5.3	GOOD
25	55	– 0.2	5.7	GOOD
24	55	– 0.5	11.1	BAD
23	60	– 0.9	20.3	BAD
22	60	– 1.2	35.4	BAD
21	60	– 1.5	53.5	BAD

Out of a total 126 persons, 71 persons felt cool-cold and 50 persons wanted warmer conditions.

71 out of 126, i.e., 56.3% were uncomfortable at 21°C. This tallies with the calculated PPD value of 53.5% evaluated above at 21°C.

Conclusion

Air conditioning systems are high-energy consuming utilities. A quick survey done on about 200 people during ACRECONF 2003 shows that there is a definite need to review the existing practice of specifying indoor conditions in an air conditioned space, without sacrificing 'comfort'. More extensive surveys could be conducted in different parts of the country. From the PMV, PPD index, it may be noted that the most acceptable comfortable condition would be 26 °C and 50 % rh for normal office working and dressed in usual summer office wear. Raising the indoor temperatures by 1–2 °C only is expected to reduce power consumption substantially.



Hi-tech Thermal Comfort Survey Form

Date . . . . . Time . . . . . .

Tick ✓ as appropriate

1. Gender
   - ☐ Male ☐ Female
2. Age
   - ☐ 20 – 30 yrs ☐ 30 – 40 yrs
   - ☐ 40 – 50 yrs ☐ 50 – 60 yrs
   - ☐ 60 yrs & above
3. Clothing I am wearing
   - ☐ Undervest ☐ Shirt (full sleeves)
   - ☐ Shirt (half sleeves) ☐ Jacket/Cardigan
   - ☐ Long Trousers ☐ Salwar Kameez
   - ☐ Saree ☐ Skirt/Blouse
   - ☐ Sandals ☐ Shoes with socks
4. At this time I feel
   - ☐ Hot ☐ Warm
   - ☐ Slightly Warm ☐ Neutral
   - ☐ Slightly Cool ☐ Cool
   - ☐ Cold
5. I would prefer to be
   - ☐ Much warmer ☐ Bit warmer
   - ☐ No Change ☐ A bit cooler
   - ☐ Much cooler
6. Skin Moisture (Perspiration)
   - ☐ None ☐ Slight
   - ☐ Moderate ☐ Profuse

References

1. Anil Misra – Thermal Comfort (personal communication)
2. *ASHRAE Handbook – Fundamentals - 1997*
3. *A survey of Thermal Comfort in Pakistan toward new indoor temperature standard* – Fergus Nicol and Others – School of Architecture, Oxford Brookes University - July 1994
4. *A tale of two populations: thermal comfort in airconditioned and naturally ventilated offices in Thailand* – John F. Busch (Energy and Building, 18 (1992) 25 - 249.
5. *Tropical Summer Index – a Study of Thermal Comfort of Indian Subjects* – M R Sharma and Sharafat Ali – Building and Environment, Vol. 21, No. 1: pp. 11-24, 1986.