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# Thermal Comfort of Green Energy Office (GEO) Building

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**ABSTRACT:** Office is the most suitable type of building for the application of energy efficiency and good indoor environmental quality measures. This is justified by the fact that such measures can promote sustainability to the future occupants, and ensure a comfortable and healthy environment for workers purposes. The purpose of this study is to investigate the thermal comfort during the cycle of process works in workplace. The environmental factors were measured using thermal comfort apparatus. The time series data of fluctuating level of factors were plotted to identify the significant changes of factors. Then the thermal comfort of the workers was assessed by using Predicted Mean Vote (PMV). Further Predicted Percentage Dissatisfied (PPD) is used to estimate the thermal comfort satisfaction of the occupant. The thermal comfort assessment of this workplace which is slightly warm following by thermal sensation and likely to be dissatisfied by the occupant. The result indicated that the activity level and clothing more influenced comfort to the occupants.

**KEYWORDS:** Thermal comfort, green energy office, PMV, PPD

## I. INTRODUCTION

In recent years, Malaysia's energy consumption has increased and become comparable to larger energy consumers worldwide. In 2002 the energy consumption was 2.8 MWh per capita and projections show a significant increase in the energy demand. Malaysia has one of the fastest growing building industries worldwide, where the corresponding energy demand would significantly increase in the next coming years (Ahmad, 2004). It is a well known fact, that the environmental factors influence the performance of a human being. Thermal stress, high humidity and insufficient illumination are often the reason for the limitation of the ability to fulfill a certain task. But what about the situation, this task is to be fulfilled at a certain company? The limitation of processing this task, is affecting the productivity of the company. If the decrease in productivity is lasting for a longer period, and many employees have to deal with these circumstances, the effect to the productivity can be enormous. The loss of each worker will affect the others and add up. The condition of the environment of a company seems to be very important with respect to the productivity and hence the success.

A number of studies have found that, air-conditioned building: This has sealed windows and cooling is available at all times of the year. Space conditions are tightly controlled. In this case low-energy design requires optimization of the HVAC plant, for

example minimizing the use of heating and cooling at the same time as fan power consumption. Typically, the air will also be subject to particle filtration and humidity control (Holmes, 2007).

Thermal comfort is recognized as a key parameter for a healthy and productive workplace. At the same time, lowering energy use in commercial building is vital if a significant reduction in greenhouse gas emissions is to be achieved. Traditionally thermal comfort has been achieved at the expense of significant energy use for heating and/or cooling. In another major study, Taylor et al. (2008) found that a well-designed building should be able to provide good thermal comfort, while simultaneously having low energy consumption. Thermal comfort can be defined as that condition of mind which expresses satisfaction with the thermal environment (Ho et al., 2008). The reference to 'mind' indicates that it is essentially a subjective term; however, there has been extensive research in this area and a number of indices exist which can be used to assess environments for thermal comfort (Fanger, 1970; Shek and Chan, 2008). However Ibrahim et al. (2007) suggested three conditions for comfort; these are that the body is in heat balance and that the mean skin temperature and sweat rate are within limits required for comfort. Conditions required for heat balance can be derived from a heat balance equation. Mean skin temperatures and sweat rates that are acceptable for comfort have been derived from empirical investigation (Holmes and Hacker, 2007).

Predicted Mean Vote (PMV) is a parameter for assessing thermal comfort in an occupied zone based on the conditions of metabolic rate, clothing, air speed besides temperature and humidity. PMV values refer the ASHRAE thermal sensation scale (Holmes and Hacker, 2007) that ranges from -3 to 3 as follows: 3 = hot, 2 = warm, 1 = slightly warm, 0 = neutral, -1 = slightly cool, -2 = cool, -3 = cold. Figure 1 summarizes the overall process of using the six variables associated with thermal comfort sensation to evaluate the PMV (ASHRAE, 2005). The general comfort equation developed by Fanger (1970) to describe the conditions under which a large group of people will feel in thermal neutrality is too complex and cannot be used in real time applications:

The parameters are defined as follows:

PMV= Predicted mean vote  $M =$  Metabolism ( $W m^{-2}$ )

$W =$  External work, equal to zero for most activity ( $W m^{-2}$ )  $I_{cl} =$  Thermal resistance of clothing ( $Cl_0$ )

$f_{cl} =$  Ratio of body's surface area when fully clothed to body's surface area when nude

$T_a =$  Air temperature ( $^{\circ}C$ )

$T_{mrt} =$  Mean radiant temperature ( $^{\circ}C$ )  $V_{air} =$  Relative air velocity ( $m sec^{-1}$ )

$P_a =$  Partial water vapor pressure (Pa)

$h_c =$  Convective heat transfer coefficient ( $W m^{-2} K$ )

$T_{cl} =$  Surface temperature of clothing ( $^{\circ}C$ )

Furthermore, the equation for PPD is given by Eq. 1:

$$PPD = 100 - 95 \exp(-0.03353 PMV^4 + 0.2179 PMV^2)$$

Predicted Percentage Dissatisfied (PPD) is used to estimate the thermal comfort satisfaction of the occupant. It is considered that satisfying 80 of occupant is good: That is, PPD less than 20% is good (Guan et al., 2003).

Improving workers' productivity, occupational health and safety are major concerns of industry, especially in developing countries. However, these industries are featured with improper workplace design, ill-structured jobs, mismatch between workers' abilities and job demands, adverse environment, poor human-machine system design and inappropriate management programs (Roberto et al., 2008). Light, noise, air quality and the thermal environment were considered factors that would influence the acceptability and performance on the occupants of premises. ISO 7730 (1994) stated that lower emotional health is manifested as psychological distress, depression and anxiety, whereas lower physical health is manifested as heart disease, insomnia, headaches and infections. These health problems could lead to organizational symptoms such as job dissatisfaction, absenteeism and poor work quality. Irritated, sore eyes and throat, hoarseness, stuffy congested nose, excessive mental fatigue, headache and unusual tiredness were all signs of the negative workplace environmental conditions (Fanger, 1970).

A field study was conducted to examine thermal comfort conditions in building which is green energy office building. The main objectives of this study were to assess predicted means vote (PMV) in determining occupant thermal sensation votes with radiant cooling and the applicability of ISO 7730 in a radiantly cooled environment and analyze the main factors affecting occupant thermal comfort.

## II. METHODS

### Physical Measurements

Physical data for the indoor environment of the selected workplace were measured by thermal comfort instrument as illustrated in Figure 1. Subject's thermal response towards the surrounding thermal environment, and subjects personal data such as age, gender, weight, height, etc., were obtained by means of the questionnaire. Thermal responses, based on the seven-point scale: cold (-3), cool (-2), slightly cool (-1), slightly warm (+1), warm (+2) and hot (+3), were collected from different groups consisted of a different number of subjects. All the measurements were carried out between 8.00 am to 6.00 pm. The data were collected within a 4 days period.



Figure 1: Thermal Comfort Instrument in work place

**Job description:** It was built on a concept which focused on the green technology innovation to minimize energy demand load, efficient use of fossil fuel via taking into account the environmental concern, the usage of renewable energy but without compromising user comfort and safety.

**Building description:** The Green Energy Building concept of this building applied both combinations of advance and currently available Energy Efficiency, EE and Renewable Energy, RE technology integrated into the building early during design concept stage. By lowering and keeping the buildings energy load as low as possible through the implementation of these energy efficient elements, less energy requirement for energy generation by the BIPV system is needed.

### III. RESULTS AND DISCUSSION

In this section the collected data was discussed. Thermal comfort is examined, with exploration of the physical parameters such as air temperature, wind speed and humidity. The develop PMV were used to analyze the relationship thermal comfort in the workplace selected. All these data are correlated with the results of the assessment of thermal comfort and health as perceived by the occupants. The air temperature within 4 days was increasing during the day. As shown in Figure 2, the temperature in day 2 was higher than others. A small drop can be noticed during the time of the first break. It can be seen clearly in Figure 2. These stations were operated by workers, wearing shirts with short sleeves, trousers, socks, shoes, underpants and the work was only rated as sedentary activity (office cloth). The according values are 1.2 met and 1.0 Clo. Hence the metabolic rate is 70 W/m<sup>2</sup>. From Figure 3, the wind speed in 4 days was higher at the morning and decrease at the evening. After lunch break, the wind speed increase again and drop at the evening. It can be seen from the graph in Figure 4, the humidity curve is the inverse of the temperature curve. What is interesting in Figure 3 were the relative humidity decreases consistent and increase again after 3.00 pm.

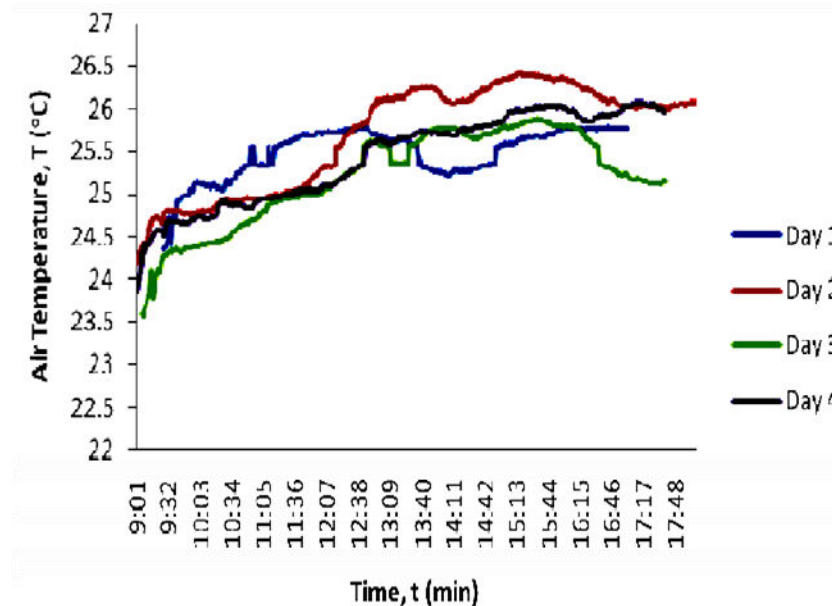


Figure 2: Air temperature measured at the workplace

#### IV. CONCLUSION

Returning to the aim posed at the beginning of this study, it is now possible to state that scale for sensation vote for PMV was slightly warm that was 0.98. The following conclusions can be drawn from the present study that 74% are likely to be satisfied by the occupant in the GEO buildings. This study was shown that this place was not comfortable for occupant. An implication of this is the possibility that the thermal comfort of a factory worker depends on there being an average skin temperature (resulting from the combination of climate, clothing and metabolic heat production). The purpose of heating or cooling enclosures to be occupied by human being is to provide thermal comfort. A given system will be judged by the occupants according to its ability to satisfy this demand and it is therefore obvious that a rational calculation of heating and air – conditioning systems must begin with the conditions for comfort. The activity level and the thermal resistance of clothing are determined, depending on the purpose for which the space will be used, and the comfort equation gives all combinations of the environmental variables which will create optimal thermal comfort. Therefore there are many possibilities for satisfying the comfort demand. However, for a given room, the environmental system chosen, the thermal properties of the room and the outdoor conditions will jointly establish certain dependence between the variables. Clearly it is important to ensure that the level of dissatisfaction with the thermal environment is kept to a minimum, preferably to no more than 5% of the people populating a building.

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