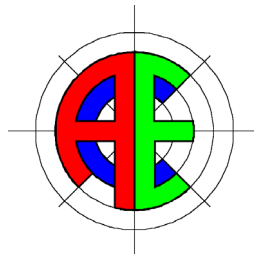


Melbourne City
Council

Adaptive Thermal Comfort Report

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design advice

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EXECUTIVE SUMMARY

The Melbourne City Council Offices will be a showcase green office building with an array of environmental and energy saving options incorporated into the design. As a result, the design team are constantly looking for ways to introduce energy saving innovations into the design. The design team has asked itself whether recent research into adaptive thermal comfort can have implications on the internal conditions for the office space. This report investigates these possibilities.

To date, thermal comfort has been an important consideration in the design of the new offices for Melbourne City Council. Research into thermal comfort has provided some interesting outcomes, particularly in the field of adaptive thermal comfort. This report investigates the possible implications of adaptive thermal comfort on the internal conditions of the Melbourne City Council offices.

This paper includes a study of the issues involved with adaptive thermal comfort. The research has shown that, in order to provide an indoor environment where relaxed internal conditions can be provided without significantly compromising comfort, an office space with operable windows would be required. In such a space, the occupants would be comfortable with warmer maxima and colder minima as a result of the perception that they have more control over their internal environment.

The design of the Melbourne City Council offices has been driven towards an open-plan design both at the request of the client, and to aid with night purge ventilation. The problems associated with operable windows in such an office environment, combined with the location of the building and additional problems such as noise pollution from outside, prevent the successful adoption of operable windows (for use during the day) in the design. A natural ventilation study already carried out by AEC for the Melbourne City Council offices has shown that natural ventilation is not suitable for maintaining conditions all year round without the use of additional cooling systems.

A controlled, conditioned indoor environment has therefore been the basis for design.

Current research on adaptive thermal comfort indicates that internal conditions cannot be relaxed in a fully air conditioned indoor environment if thermal comfort is to be maintained. The thermal comfort for fully air conditioned spaces is more accurately determined using current thermal comfort benchmarks (such as PMV).

The aim of the Melbourne City Council Office building design is to provide excellent thermal comfort for its occupants and it is for this reason that we recommend that the internal conditions provided by the proposed HVAC system be kept at levels typical of contemporary air conditioned office buildings.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	I
TABLE OF CONTENTS	II
1 INTRODUCTION	1
2 OUTCOMES FROM CURRENT LITERATURE	2
2.1 Thermal Comfort	2
2.2 Adaptive Thermal Comfort	4
3 CONDITIONS AT MELBOURNE CITY COUNCIL OFFICE	5
3.1 The Design Brief	5
3.2 The Requirements	5
3.3 Responding to the Brief	5
4 DISCUSSION	7

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1 INTRODUCTION

The issue of adaptive thermal comfort has been popularised by recent research, suggesting that under certain conditions, the internal temperature maxima and minima can be relaxed.

This was considered worthy of further investigation for the Melbourne City Council Offices development, largely because of the potential energy savings which can be obtained from relaxing internal conditions.

As a result, a brief literature study has been carried out, investigating the theories of adaptive thermal comfort. This study focuses on the paper by Dr Richard de Dear from Macquarie University, titled "Developing an Adaptive Model of Thermal Comfort and Preference".

The current design of the building and aims & objectives of the client are considered as part of this study, in order to determine how appropriate a reaction to the findings of this research will be for the Melbourne City Council Office development.

2 OUTCOMES FROM CURRENT LITERATURE

The notion of “Thermal Comfort” as a means of determining the satisfaction of occupants in a building is an important benchmark. It is developing as the new benchmark for measuring the necessary internal conditions. As the notion of thermal comfort becomes accepted in building design, it is inevitable that designers will seek to use thermal comfort principles to push the limits of standard building design.

2.1 Thermal Comfort

Thermal comfort is a measure of how comfortable the indoor environment is perceived to be by its occupants. Thermal comfort modelling is used to give an indication as to the proportion of occupants who notice warmth or coolness in a space. As the proportion of occupants noticing a certain thermal environment (such as warmth or coolness) increases, the level of thermal comfort deteriorates. Where this proportion of “dissatisfied” occupants is low, the level of thermal comfort is considered to be good.

Thermal comfort is not only related to air temperature. This is because an individual’s perception of temperature is based on a combination of factors. A number of heat exchanges between the human and the surrounding environment affect the perception of comfort. These include the following:

- Convective heat. The body’s contact with the surrounding air, its temperature related to the body and direction of flow provides approximately 35% of the perceived comfort.
- Radiant effects. This is the heat radiated from all objects, including the body. The amount and direction of radiant heat exchange is dependant on the temperature of the surfaces that are in the space relative to the body’s surface temperature. This accounts for 40% of the perceived comfort.
- Evaporative effects. This is the heat lost by the body through evaporation of perspiration from the skin surface. The relative humidity of the space has a strong influence on this cooling process, as does the air velocity in the space. Evaporative effects determine approximately 25% of the perceived comfort.

As a result, the level of thermal comfort is derived from a number of environmental parameters, including the air temperature, the mean radiant temperature, the air velocity and the relative humidity in the space. It also considers the level of activity of the occupants (people doing heavy labour are more likely to feel hot than people seated at a desk) and the type of clothing worn (an environment may seem warmer to someone wearing a suit, than to someone in shorts and a t-shirt).

An international standard (ISO 7730-1993(E)) has been created for determining thermal comfort. The standard describes thermal comfort using two related terms; Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD). PMV is the benchmark for the International Standard. Conditions under different PMV levels are described in the table below.

Predicted Mean Vote (PMV)	Internal Conditions
+3	hot
+2	warm
+1	slightly warm
0	neutral
-1	slightly cool
-2	cool
-3	cold

Predicted Mean Vote is literally what it means. It is based on a mathematically generated response, based on empirical data of what each person in the space would "vote" if asked for their opinion on the state of the indoor environment, with each person selecting one of the options in the table above. The PMV is the mean result from all those "votes".

The PPD makes it easier to understand the PMV values, by relating it to a predicted level of occupant dissatisfaction with the indoor environment. At a PMV of 0, only 5% of occupants would signal dissatisfaction with the indoor environment. At a PMV of 3, 95% of occupants are dissatisfied. Figure 1 shows the relation between PMV and PPD.

Figure 1 shows that at a PMV of 1, approximately 25% of occupants are uncomfortable, with a large proportion of those occupants slightly uncomfortable (shown in orange), and a small proportion (approximately 5% - shown in red) being very uncomfortable. At a PMV of 2, the percentage of uncomfortable occupants increases to 75% (denoted by the orange and red bars), of whom a significant proportion are very uncomfortable (denoted by the red). This graph shows that if the PMV can be kept within +1 and -1, then the percentage of very uncomfortable occupants can be kept to no greater than 5%, and the percentage of slightly uncomfortable occupants can be kept to no greater than 20%.

Note that this method acknowledges that at no time will 100% of occupants be satisfied.

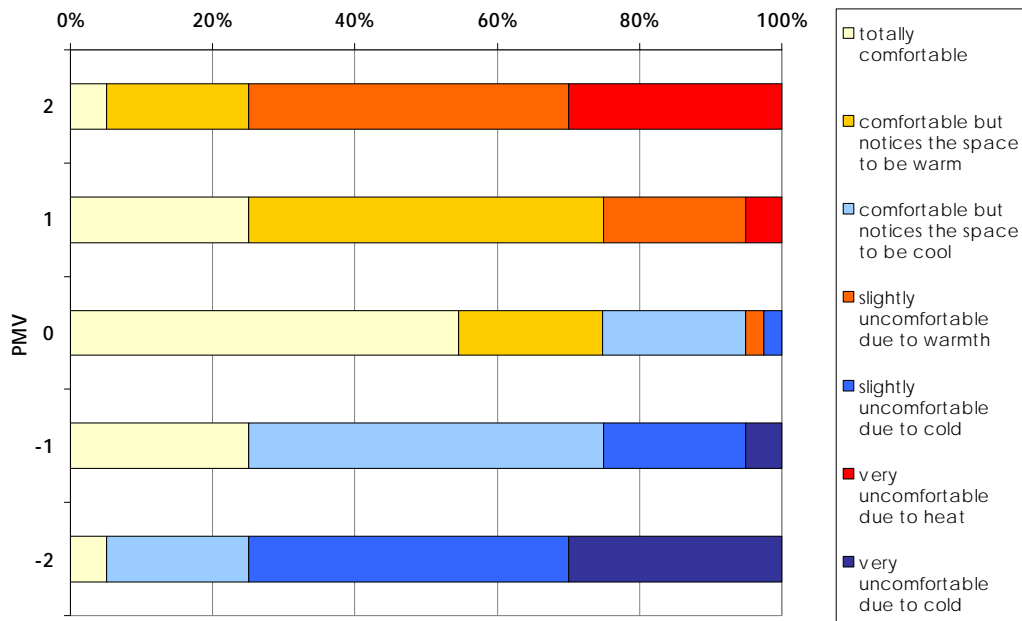


Figure 1: State of occupants for different PMV levels

2.2 Adaptive Thermal Comfort

The notion of adaptive thermal comfort is summarised well in Nick Baker's paper "We are all outdoor animals" (2000), and has been studied intensively by David Wyon and Richard de Dear.

Adaptive thermal comfort introduces the notion that people will tolerate a wider range of temperatures and internal conditions when more control is allowed over their internal environment. The best example of this is explained by de Dear, who notes:

*"Occupants in naturally ventilated buildings were tolerant of a significantly wider range of temperatures explained by a combination of both behavioural adjustment and psychological adaptation."*¹

David Wyon's research² also supports this notion, and he found that occupants in offices with operable windows and individual temperature controls tended to be far more satisfied with their environment than occupants in "sealed boxes".

De Dear breaks down adaptation into three categories – behavioural, physiological and psychological.

Behavioural adaptation includes actions such as putting on a jumper, opening a window or adjusting the climate controls. Physiological adaptation, according to de Dear, is broken down into genetic adaptation and acclimatisation, whilst psychological adaptation depends on expectations of the environment in a perceived space (ie opening a window may change one's perceptions of how the conditions in the space would change and therefore they would be less likely to feel discomfort at such a change).

Opportunities for adaptive thermal comfort are therefore restricted to situations where occupants have a greater degree of control over their environment – principally in environments where natural ventilation control is possible. de Dear writes:

*"Adaptive opportunity can be thought of as a continuum – at one extreme is the climate chamber, and at the other extreme we find the single-occupant room with full adaptive possibilities from operable windows through to task-ambient air conditioning."*³

To summarise, adaptive thermal comfort opportunities are restricted to environments where adaptation is available. The occupants must feel as though they have control over the environment, and as though the reaction of the space to their actions is concurrent with the configuration.

Before it is possible to relax internal conditions on the grounds of an adaptive thermal environment, it must be affirmed that environment, with all its adaptive opportunities, will be provided.

¹ de Dear, R., Developing an Adaptive Model of Thermal Comfort and Preference (1998), p1

² Wyon, David P., Indoor Environmental Effects on Productivity, (1996)

³ de Dear, R., 1998, p2

3 CONDITIONS AT MELBOURNE CITY COUNCIL OFFICE

To determine whether adaptive thermal comfort evidence would be used to justify relaxed internal conditions at the new Melbourne City Council development, it is important to investigate the aims and objectives of the new development, and determine whether the adaptive comfort options can be incorporated into the design without jeopardising those objectives.

3.1 The Design Brief

The client has specifically noted a number of important features to be incorporated into the design.

Included amongst the important issues which AEC has had to consider during the design process is the desire of the client to provide a building that:

- provides best-practice indoor environmental quality
- provides a low-energy HVAC solution
- allows for an open plan tenancy
- provides a high quality working environment

The relevance of these issues is discussed below.

3.2 The Requirements

Considering the stated requirement, that the council offices provide an internal thermal environment equivalent to or better than standard air-conditioned office environments, two distinct paths are possible in the design of Melbourne City Council offices.

1. The climate controlled office

The climate controlled office design would take a design approach similar to most modern offices, requiring a tightly controlled, sealed office environment with fresh air, heating and cooling provided mechanically. Within this framework, the energy consumption of the possible heating and cooling systems would be designed to be at minimum.

2. The user-controlled office

The user-controlled office design would include fully operable windows and be designed to optimise the effectiveness of natural ventilation. Task-controlled heating and cooling may also be provided to provide individual occupants with control over their own thermal conditions. Within this framework, the energy consumption of the possible systems would be designed to be at a minimum.

3.3 Responding to the Brief

If adaptive thermal comfort internal conditions were to be used for this design, then option 2, the use-controlled office would need to drive the design. According to the Melbourne City Council brief, however, there are a number of problems associated with this office design. These are described below:

- Open Plan office

The proposed office-layout for the Melbourne City Council offices includes an open-plan style office space. This type of layout would make individual climate control very difficult, as one person opening a window would affect the entire office environment, even if the other occupants were happy with conditions before the window was opened.

As previously described, the user-controlled office environment is more suited to a fully partitioned and sectioned off office environment. It is important to note that the open plan office is necessary for the successful operation of the night purge ventilation. This ventilation is an important comfort and energy element, as it will cool down the offices at night in summer, reducing the energy required in the morning to cool the building down.

- Noise

The provision of operable windows in the Melbourne CBD on a busy street is unlikely to satisfy the noise aspirations of the office design. Therefore whilst the provision of operable windows may provide an opportunity for a more relaxed thermal environment, this will be offset by the additional noise exposure from the outside, particularly for the lower floors.

These two problems have severely restricted the capacity to incorporate a design with operable windows on the facades.

As a result, the climate controlled office has been selected as the most appropriate way to satisfy the needs of the client. Indoor Environmental Quality will be provided by 100% fresh air and chilled ceilings, and the innovative design will be highly energy efficient. Some adaptive control will be afforded to the occupants, who will be able to adjust their fresh air intake (down to a minimum) from the floor vents.

These initiatives will be discussed in greater detail in the schematic design report.

4 DISCUSSION

The Melbourne City Council offices' design seeks to minimise energy use at every opportunity. As a result, this paper has investigated the opportunity to relax the internal conditions of the office spaces (and hence reduce energy consumption) through recent research in adaptive thermal comfort.

Thermal comfort is an important consideration in the design of the new offices for Melbourne City Council. Recent findings in thermal comfort have shown that occupants will remain comfortable in environments with higher temperature ranges if adaptive responses to their surroundings are available.

A study of the issues involved with adaptive thermal comfort has shown that, in order to provide an indoor environment where relaxed internal conditions can be provided without significantly compromising comfort, an office space with operable windows would be required. It was therefore concluded that to introduce relaxed internal conditions into the Melbourne City Council offices, operable windows and individual climate control would be necessary.

The design of the Melbourne City Council offices has been driven towards an open-plan design at the request of the client. It has been found that the problems associated with operable windows in such an office environment, combined with the location of the building and additional problems such as noise pollution from outside, prevent the successful use of operable windows during the daytime.

A controlled, conditioned indoor environment, with windows only operating as part of a night purge system, has therefore been the basis for design.

Current research on adaptive thermal comfort indicates that internal conditions cannot be relaxed in a fully air conditioned indoor environment if thermal comfort is to be maintained. The thermal comfort for fully air conditioned spaces is more accurately determined using current thermal comfort benchmarks (such as PMV). Unfortunately this limits the opportunity to relax internal conditions for this building.

The aim of the Melbourne City Council office building design is to provide excellent thermal comfort for its occupants. The provision of excellent thermal comfort is clearly a priority over minimising energy use, even though design is focussed on doing both. The outcomes of this research indicate that relaxing internal conditions will jeopardise the comfort of the offices to an unsatisfactory degree and as a result, we recommend that the internal conditions be maintained at a standard typical of contemporary office buildings.