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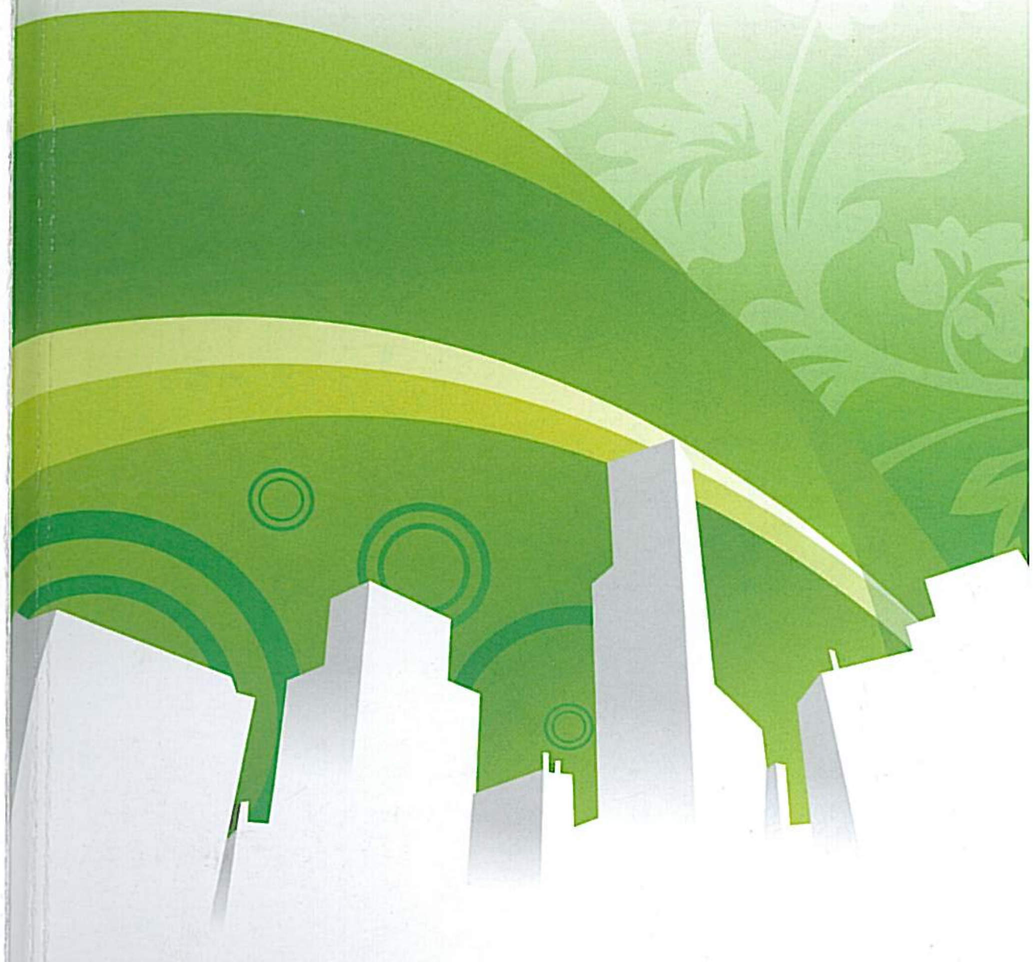
The Green Building Handbook South Africa

The Essential Guide

Volume 2



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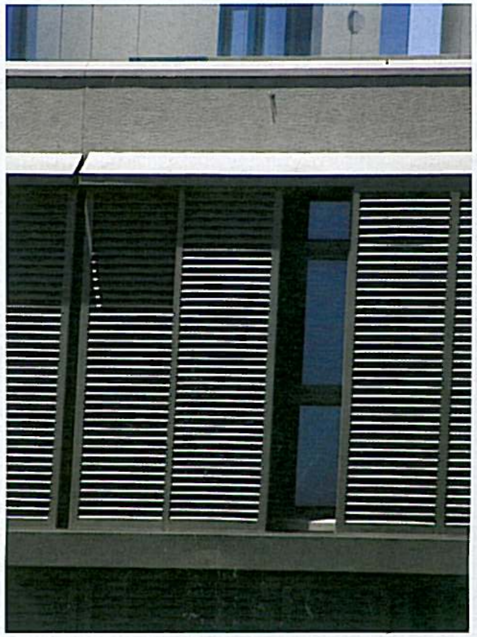

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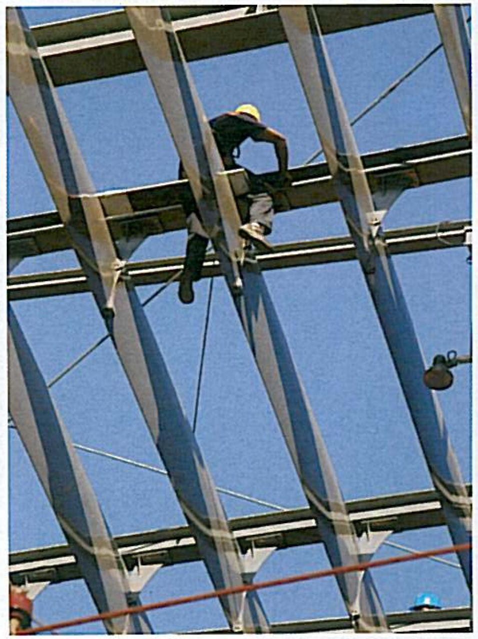

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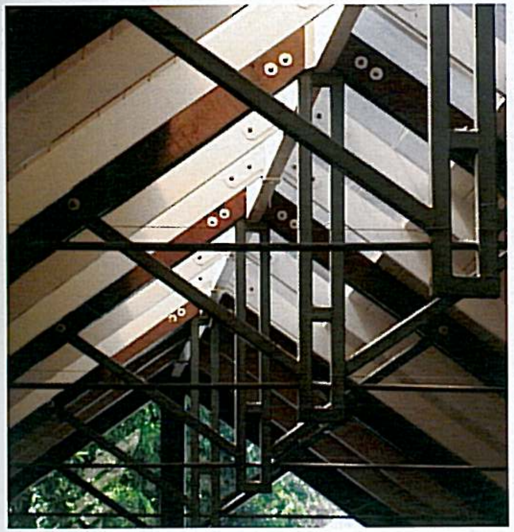

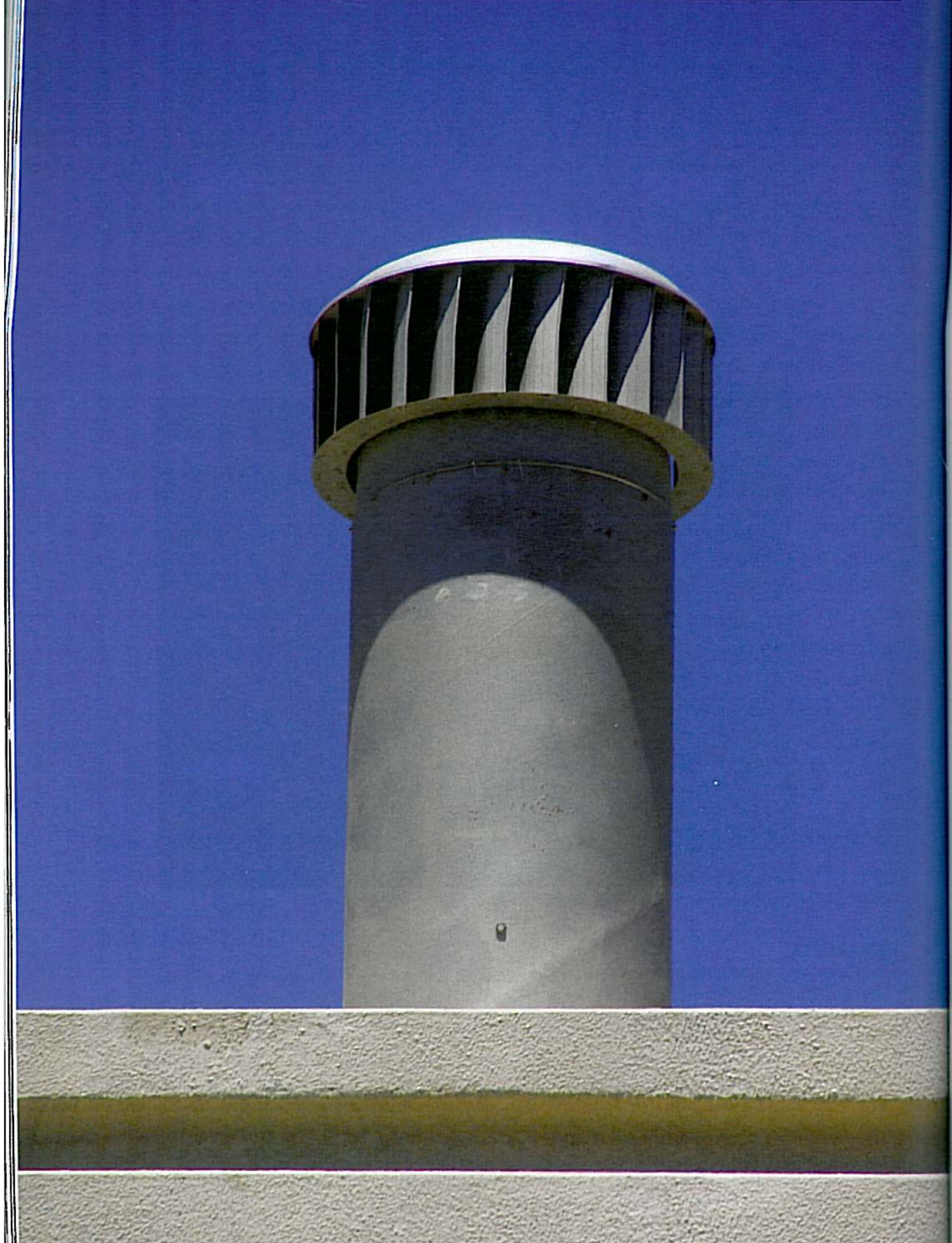

THERMAL COMFORT

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Researcher
CSIR

INTRODUCTION

Thermal comfort has been defined (ASHRAE 55-2004) as "that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation". While this definition may seem vague, it highlights correctly that thermal comfort is a qualitative judgement and is affected by such things as physical, physiological and psychological influences.

Thermal comfort is influenced by environmental parameters as well as other influences including asymmetric heating and cooling conditions which will be discussed. Additionally, some aspects of thermal comfort may be exploited so as to enable a building to operate within a wider range of temperature limits, saving energy while still satisfying the majority of building occupants. It is also noted that thermal comfort varies significantly between individuals and it is generally not possible to provide a thermal environment in which all occupants will be comfortable.

PREDICTED MEAN VOTE

The predicted mean vote (PMV) is a commonly used index to represent and to predict thermal comfort. The predicted mean vote index is based on qualitative testing, where a large sample of humans was subjected to different thermal environments and their thermal comfort was recorded. It is also based on fundamental heat transfer mechanisms. Ultimately a mathematical expression has been developed that can be used in order to predict the PMV.

PMV uses a seven point thermal sensation scale as shown below:

Value	Description
3	Hot
2	Warm
1	Slightly Warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

Table 18.1: Seven point thermal sensation scale (ASHRAE Handbook, Fundamentals, 2005)

The mathematical expression of PMV includes such variables as air temperature, mean radiant temperature, metabolic rate, clothing insulation, air speed and humidity.

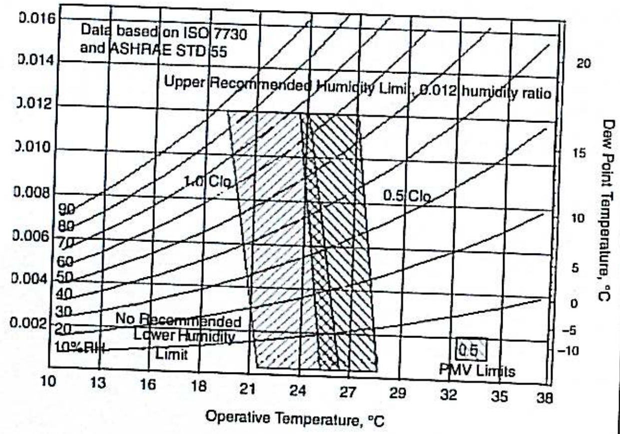

Figure 18.1: Acceptable range of operative temperature and humidity (ASHRAE Standard 55-2004)

Thermal comfort, especially within the built environment, is dominated by air temperature, humidity and clothing insulation, and therefore the comfort space can be expressed in the graph above as a function of these variables. Unfortunately, due to the variability among humans, not all will be comfortable within any specific thermal environment.

PREDICTED PERCENTAGE OF DISSATISFIED

Predicted Percentage of Dissatisfied (PPD) is a metric to express what percentage of people are going to be uncomfortable within a particular environment and is related to the PMV as shown in the graph below.

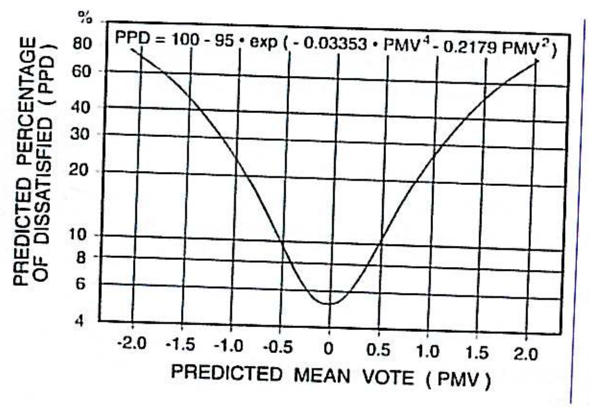

Figure 18.2: Predicted percentage dissatisfied (PPD) as a function of predicted mean vote (PMV) (ASHRAE Standard 55-2004)

Ideally, a PMV ranging between -0.5 and 0.5 is recommended; however, a range between -1 and 1 can still be thought of as being good.

METABOLIC ACTIVITY

Metabolic activity refers to the amount of heat that a person generates while performing a particular activity. While accurate data regarding the particular activities that will be performed within spaces are often not available during the building design process, giving closer attention to such details when it is available, or when it can be accurately assumed, can yield a greater accuracy in the heating and cooling load calculations of a building.

Activity	W/m²
Sleeping	40
Seated, quiet	60
Standing, relaxed	70
Reading, seated	55
Writing	60
Typing	65
Filing, seated	70
Filing, standing	80
Walking about	100
Lifting/packing	120
Tennis, singles	210-270
Wrestling, competitive	410-505

Table 18.2: Typical metabolic heat generation for various activities (ASHRAE Handbook, Fundamentals, 2005)

Type of human	Skin surface area m²
Average male European	1.8
Average female European	1.6

Table 18.3: Average human surface areas (ASHRAE Handbook, Fundamentals, 2005)

Often, the activities of individuals within particular spaces vary. Under these conditions it is generally satisfactory to use a weighted average, provided that activities alternate frequently, several times an hour.

CLOTHING

The level of clothing that the building occupants are wearing will have a large influence at which temperatures they will be comfortable. Additionally, assumptions regarding clothing levels need to be made in order to perform calculations on expected thermal comfort of building occupants. What can be expected from the clothing that building occupants will be wearing depends largely on the corporate culture of the company that occupies the building and on its dress code. While it would be convenient to assume or insist that building occupants dress warmly during cold weather to reduce the amount of active heating, it would be prudent to ensure that such a policy fits well and would be readily accepted by the company and the individuals who are expected to work in such an environment.

An office building's primary function is to provide a safe and comfortable working environment and comprising this for energy savings would be ill advised. Production losses from uncomfortable employees could greatly exceed any financial gains that could be derived form reducing the active heating load of the building.

ASYMMETRIC THERMAL RADIATION

Within thermally neutral environments, asymmetry in the surface temperatures of the surrounding surfaces has the potential to cause significant discomfort. The surfaces exchange heat with people in the space through radiative heat transfer. The amount of heat radiated is related to the difference in temperature between the person and the surfaces. The asymmetry in the rate of heat exchange over the surface area of the people within the space causes discomfort.

Common causes of asymmetric thermal radiation could include cold windows, uninsulated walls, cold products and improperly sized heating panels.

People are generally more sensitive to asymmetric thermal radiation caused by an overhead warm surface and a vertical cold surface than an overhead cool surface and a warm vertical surface, which causes much less discomfort for the same asymmetry.

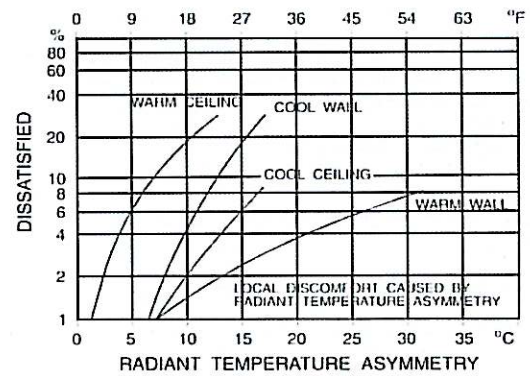

Figure 18.3: Local thermal discomfort caused by radiant asymmetry. (ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy)

DRAFT

Draft can cause significant discomfort, not only in buildings but also within cars, trains and aircraft. The perceived discomfort from draft is primarily dependant on the velocity of the draft; however, the air temperature of the draft is also significant.

Drafts also have the potential to allow people to feel thermally comfortable at higher temperatures, depending on the velocity of the draft. Introducing a draft into a building could then allow the designer to define a slightly higher operational temperature and thus save energy on active cooling. Such a strategy should be implemented only if building users have direct control on the velocity of the drafts due to the potential of drafts to cause discomfort and because of the high variability between individuals in how they perceive the discomfort from drafts.

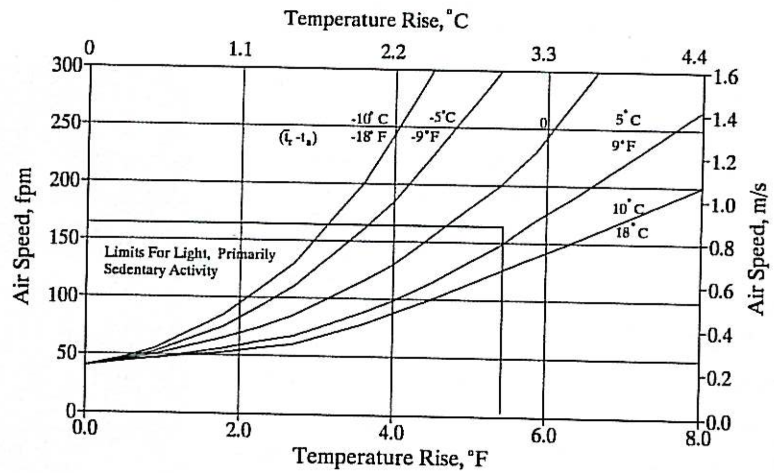

Figure 18.4: Air speed required to offset increased temperature (ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy)

While not directly relating to comfort, the combinations of air speed and temperature defined by the lines in the figure above result in the same heat loss from the skin. The value presented on the temperature curves is the difference in radiant and air temperatures. The temperature rise is the amount by which the temperature will need to be increased in order to maintain the same rate of heat transfer.

Thus, if drafts exist within the space, then the occupants can be expected to be comfortable at a slightly higher temperature. Increasing air speed for cooling is more effective in environments that have high radiant temperatures and low air temperatures.

VERTICAL AIR TEMPERATURE DIFFERENCE

Significant discomfort can also be caused due to vertical air temperature gradients over the length of a human despite the human being thermally neutral. Generally, the air temperature at head level

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Peter Groves and Associates CC was formed in January 1991 to offer a supply service to Contractors and associated services to the Airconditioning Industry. By 1995 the company had grown and became Peter Groves Airconditioning Sales SA (pty) Ltd, and started establishing agencies with various well known brands such as Electra and York.

After a short period we were appointed as agents in Zimbabwe for the above and began to further develop markets into Southern Africa. Today Peter Groves Airconditioning Sales market and sell the following products with a staff compliment of 18 people in Johannesburg and selling agencies in Durban, Cape Town, Gaborone and Mauritius.
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- Sinko Fan Coils
- Sabiana fan coil products
- LG Airconditioning products including Multi V systems
- EDC Condensate pumps and low ambient controls (sole agent)
- Airconditioning unit Installation accessories from Europe

Products:
LG Digital Appliance
LG provides a wide range of tailored commercial air conditioning products suited to buildings in a variety of types and sizes.
Clivet
Clivet proposes technically advanced systems, able to meet the modern comfort needs for the most exacting applications.
Sabiana
Sabiana designs, builds and sells heating and air-conditioning products for all working and recreational environments.
EDC
EDC have been at the forefront of electronics development in the refrigeration and air conditioning industries for many years.
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Air-conditioning equipment is indispensable for office buildings, factories, amusement facilities.

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will be higher than that at the ankle level; however, it was also found that humans will accept a larger difference in vertical air temperature provided that their head is cooler (Eriksson, 1975). This is consistent with asymmetric thermal radiation with humans being more comfortable with overhead cooling than with overhead heating.

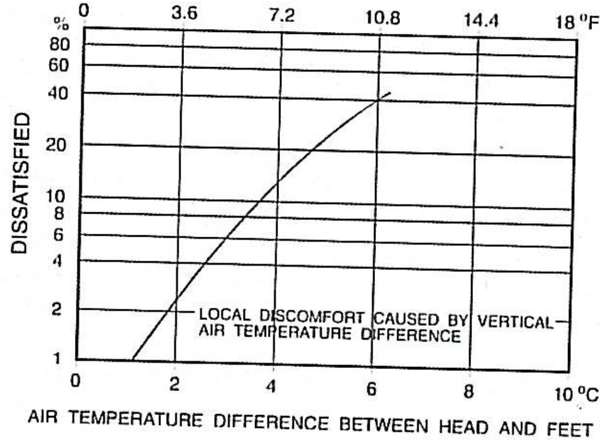

Figure 18.5: Air temperature difference between head and feet (ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy)

HOT AND COLD FLOORS

Building users have their feet in direct contact with the floor; consequently the floor temperature has a disproportionate effect on human comfort as well as also affecting the mean radiant temperature of the room. The floor temperature is particularly important where people can be expected to be barefoot or where children can be expected to play on the floor. If a floor is too cold, despite the occupants being thermally neutral, a common reaction is to increase the air temperature through active heating. Such behaviour obviously wastes energy.

The graph below describes the percentage of dissatisfied individuals in correlation with the floor temperature. The graph was developed for people wearing lightweight shoes and would be conservative for those wearing heavy shoes and should not be used where people can be expected to be barefoot.

The Green Solution to Individual Comfort Control

Rickard Air Diffusion (Pty) Ltd was established in Cape Town, South Africa in 1979. Today it is Internationally the leading producer of Variable Geometry VAV diffuser equipment and BMS compatible controls. Rickard is focused on supplying VAV Diffusers and Controls that allows for Green Intelligent Comfort Control Solutions in the HVAC Industry. The company is privately owned, managed and directed by its shareholders.

INTELLIGENT COMFORT CONTROL

Since 1985 Rickard has actively promoted its products in many countries around the world resulting in the installation of its VAV equipment in such prestigious buildings as the Rolls Royce offices-Birmingham England, New York Times-New York City, George Washington University-Washington DC, Ramat Gan Towers-Tel Aviv Israel, Telekom-Cyberjaya Malaysia, Deloitte & Touche-New York City, Clinica Girassol-Luanda Angola, Old Mutual Headquarters-Cape Town South Africa, Yellow Pages House-Sydney Australia, Movie City-Hong Kong China, Port Ghaleb Resort-El Qusier City Egypt & Madinat Jumeirah Resort Dubai to name but a few.

Green building benefits

Management Credits
Indoor Environmental Quality Credits
Energy Efficiency Credits

Networking capability

TCP/IP with Rickard Mini BMS Software
LON
BacNet

Maintain Excellent Room Comfort Conditions

Diffusers with excellent ADPI values
Diffusers ensure Air Change Effectiveness even at minimum flow
Diffusers have good throw at low flow settings

Control Capabilities

Energy saving decisions for the complete system based on actual space temperature and air volume supply information from every room.
Setpoint control in every room with over ride from BMS
Peak building energy demand control by cycling heaters at every diffuser.

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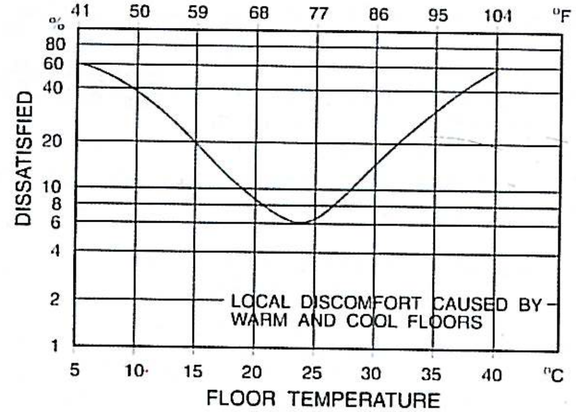

Figure 18.6: Local discomfort caused by warm and cool floors (ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy)

NATURALLY VENTILATED SPACES

While the conditions that will produce thermal comfort can generally be well-defined, field experiments have shown that the thermal responses of occupants within naturally ventilated buildings depend, in part, on the outdoor climate and may differ from thermal responses in buildings with centralised HVAC systems, primarily because of the different thermal experiences, changes in clothing, availability of control and shifts in occupant expectations.

The graph below demonstrates occupant acceptance for naturally ventilated buildings and it assumes that occupants will change their behaviour to outdoor environmental conditions such as adjusting their clothing.

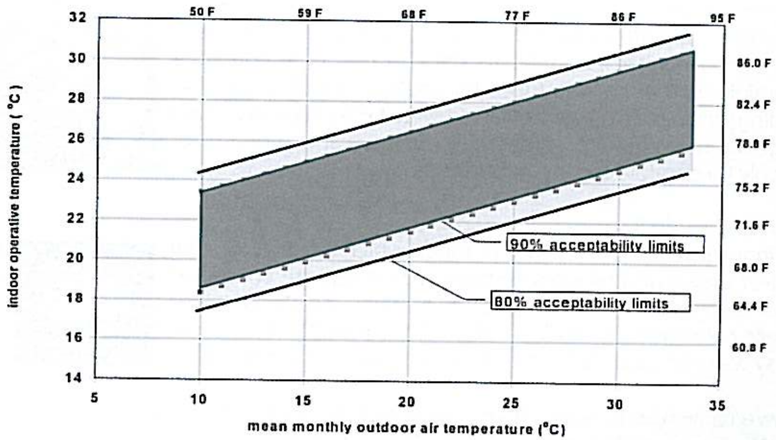

Figure 18.7: Acceptable operative temperature ranges for naturally conditioned spaces (ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy)

AGE

Interestingly, the thermal environments preferred by young and old people do not differ while performing the same activities. While metabolism decreases slightly with age, this is compensated by a lower evaporative heat loss. However, the ambient temperatures within the homes of old people are often higher than those of younger people, this is explained by lower activity levels of elderly people who are normally sedentary for a greater part of the day.

SEX

In developing the ASHRAE thermal sensation scale that is a basis of the PMV index, studies have discovered that there were variations between the sexes in how thermal comfort is perceived (Rohles, 1973; Rohles et al, 1971). The results suggest that women are more sensitive to temperature changes and less sensitive to humidity changes in reference to their thermal comfort.

SEASONAL AND CIRCADIAN RHYTHMS

Studies have also shown that there is no difference between comfort conditions between summer and winter (McNall et al, 1968). However, comfort conditions do vary over a daily cycle because the internal body temperature has a daily rhythm, with a maximum late in the afternoon and a minimum early in the morning, although such variations are small and not significant (Fanger et al, 1973).

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