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Research on the Origins of Thermal Comfort

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Abstract

General thermal comfort is defined by certain thermal conditions that, on average, affect the environment in order to ensure comfort from its broader view. On the other hand, local thermal comfort focuses on the study of areas subject to special conditions like draft, asymmetric solar radiation and local perception of air quality. In these sense, and in accordance with ASHRA, ISO and NTP Standards, it is possible to improve comfort through relevant building structural modifications like thermal inertia, its own air conditioning facilities and people's habits like working periods. An adequate combination of all these variables will let an adequate indoor ambience. In present paper it was done a deep research about the principal works about general and local thermal comfort conditions based on results of scientific research and actual ISO and ASHRAE Standards. From this research it was concluded that general and local thermal comfort researches must be focused in relate field and simulation tests. These tests will let to predict the behaviour of indoor environments and, in consequence, to improve energy saving, material conservancy and work risk prevention. Finally, future research works are proposed like new Heating Ventilation and Air conditioning control systems that operate in accordance with these simulations.

Keywords: General thermal comfort model, Percentage of dissatisfied, ASHRAE.

1. Introduction

Given the varied activities of international involvement in indoor environments [1] it is necessary to start a revision with a chronological development of the main researches and conclusions reached until now in general and local thermal comfort. In particular, it will be of special interest to develop future strategies and procedures to implement thermal conditions and energy saving in indoor ambiences.

2. General thermal comfort background

When we try to understand the general thermal comfort it is common to analyse Fanger's PMV model. This model is based on thermoregulation and heat balance theories. According to these theories, the human body employs physiological processes in order to maintain a balance between the heat produced by metabolism and the heat lost from the body.

In 1967 Fanger investigated the body's physiological processes when it is close to neutral to define the actual comfort equation. Its investigations [2] began with the determination that the only physiological processes influencing heat balance were sweat rate and mean skin temperature as a function of activity level. After it, he used data from a study by McNall et al. (1967) [3] to derive a linear relationship between activity levels and sweat rate and conducted a study to derive a linear relationship between activity level and mean skin temperature. These two linear relationships were substituted into heat balance equations to create a comfort equation to describe all combinations of the six PMV input variables that result in a neutral thermal sensation.

Once obtained an initial comfort equation, it was validated against studies by Nevins et al. (1966) [4] and McNall et al (1967) [3], in which participants rated their thermal sensation in response to specified thermal environments. To consider situations where subjects do not feel neutral, the comfort equation was corrected by combining data from Nevins et al (1966), McNall et al (1967) and his own studies, Fanger (1970) [5]. The resulting equation described thermal comfort as the imbalance between the actual heat flow from the body in a given thermal environment and the heat flow required for optimum comfort (i.e. neutral) for a given activity. This expanded equation related thermal conditions to the seven-point ASHRAE thermal sensation scale, and became known as the PMV index. Fanger (1970) also developed a related index, called the Predicted Percentage Dissatisfied (PPD). This index is calculated from PMV, and predicts the percentage of people who are likely to be dissatisfied with a given thermal environment.

Thermal comfort standards use the PMV model to recommend acceptable thermal comfort conditions. The recommendations made by ASHRAE Standard 55 [6, 7, 8] are shown in Table 1. These thermal conditions should ensure that at least 90% of occupants feel thermally satisfied.

Table 1: ASHRAE Standard recommendations.

	Operative Temperature	**Acceptable range**
Winter	22ºC	20-23ºC
Summer	24.5ºC	23-26ºC

These conditions were assumed for a relative humidity of 50%, a mean relative velocity lower than 0.15 m/s, a mean radiant temperature equal to air temperature and a metabolic rate of 1.2 met. Clothing insulation was defined as 0.9 clo in winter and 0.5 clo in summer.

3. Local thermal comfort background

At the same time that the general thermal comfort condition were defined by scientifics, it was developed research works to define the local comfort conditions related with air velocity, temperature and asymmetric radiation.

It was in 1956 that the first serious studies on local thermal comfort background began, when Kerka and Humphreys began their studies of indoor environment. However, ever since, man has had a special interest in controlling indoor environments. In these studies they init to use panels to assess the intensity of smell of three different fumes and smoke to snuff. The main findings show that the intensity of the odour goes down slightly with some increase in atmospheric humidity. Another finding obtained, indicates that in the presence of smoke snuff, the intensity of the odour goes down with increasing temperature, for a constant partial vapour pressure.

In 1972, Fanger [5] described the general thermal comfort as a material and energy balance being the basis of the actual general thermal comfort research. The ISO 7730 and the ASHRAE Standard 55-2004 reflected this theory. Two years later, Cain [9] explored the adaptation of man to four air components and to different concentrations over a period of time. The main conclusions obtained showed that there was no significant difference between pollutants. In all of these, perceptions often fell by 2.5%/s initial value until reduced to 40%.

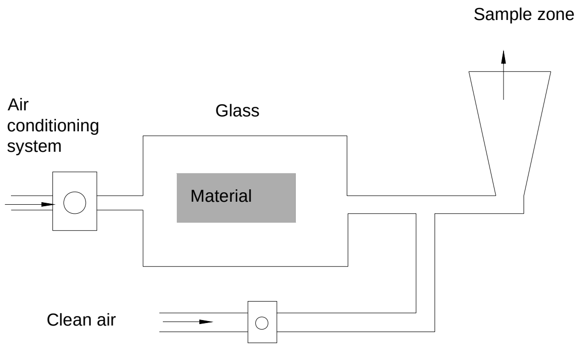
In 1979, Woods [10] confirmed the results of Kerka and concluded that smell perception of odour intensity is linearly correlated with the enthalpy of air and in 1983, Cain et al. [11] studied the impact of temperature and humidity on the perception of air quality. They concluded that the combination of high temperatures (above 25.5ºC) and a relative humidity above 70% exacerbate odour problems. Six years later, Berglund and Cain [12] discussed the adaptation of pollutants over time for different humidities. This study concluded that the air acceptability, for different ranges of humidity at 24ºC, is stable during the first hour. It was also concluded that the subjective assessment of air quality was mainly influenced by temperature conditions and relative humidity and, secondly, by the polluted air. It was also concluded that the linear effect of acceptance is more influenced by temperature than by relative humidity.

In 1992, Gunnarsen [13] et al. studied the possibility of adapting the perception of odour intensity. Such adaptation was confirmed after a certain time interval and in 1996, Knudsen et al. [14] carried out research into the air before accepting a full body and facial exposure. The problem with this test is that the process is carried out at constant temperature equal to 22 degrees Celsius and the relative humidity is not controlled.

In 1998 L. Fang, Clausen and P.O. Fanger [15] carried out an initial experiment in a chamber with clean air heated to 18ºC and 30% relative humidity, see Figure 1. In the experiment, 40 subjects without specific training were subjected to the conditions in these chambers, as is shown in Figure 1. As a precaution, they were warned not to use strong perfumes before the experiment. The subjects underwent a facial exposure; they were questioned about their first impression of the air quality inside the chamber. In this case we consider the existence of clean air where there are no significant sources of pollution and the air has not been renewed with outdoor air.

From these studies it was concluded that there is a linear relationship between the acceptability and enthalpy of the air. It also concluded that, at high temperature levels and humidity, the perception of air quality appears more influenced by these variables than by the air pollutants. All these findings need further validation, which involved the development of more experiences.

Figure 1: House heated Climpaq designed by Albrectsen in 1988.



In a second experiment this same group carried out a study of the initial acceptability and subsequent developments. For this study they used clean air and whole body exposure of individuals to different levels of temperature and humidity. This experiment was divided into two sets: one aimed at defining the feeling of comfort and the other at defining the perception of smell.

For these experiments a system was developed based on two stainless steel chambers (3.60 x 2.50 x 2.55 m) independent and united by a door that allows a camera to pass from one to the other. In this way, the individual who performs the test may turn to the second chamber at each stage of the experiment. This camera is subjected to a new odour level, temperature and/or humidity. Figure 2 shows the shape of the chamber.

The experiment focused on conducting a survey on 36 students who had not been trained in issues of indoor environments. The group was made up of 26 men and 10 women. All of them were nearly 25 years old and had their whole body exposed in the chamber. The scale of values that were employed during the survey is shown in Figure 3.

Figure 2: New experimental chamber.

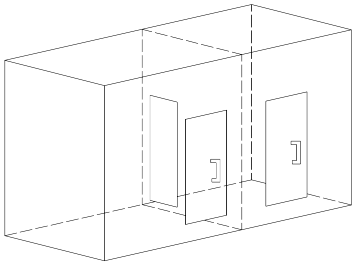
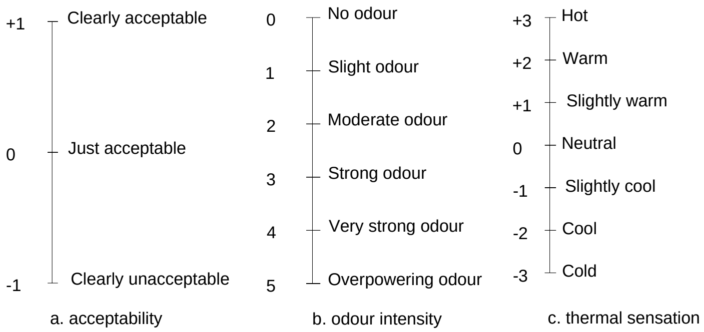


Figure 3: Used survey.



In these chambers there remained constant different temperatures and humidity within the ranges (18-28º C) and (30-70%), respectively. The number of air changes in both chambers was the same and equal to 420 l/s. The existing pollutants came from the own chamber or from the air renovation system.

Every 20 minutes existing conditions were varied which prompted the individual to change camera. The questionnaires were filled in every 2.5, 5, 10, 15 and 20 minutes. Throughout the process the subjects could adapt their clothing to the environment around them to achieve thermal neutrality.

In the second round of experiments individuals were submitted to a similar procedure to the previous one. In this case a contaminated source like PVC was introduced, and air renovation descended to 200 l/s. The pollutants were hidden in the camera and individuals were introduced in groups of six to answer the survey. The findings for the first experiments indicated that the alarm immediately jumps depends on the temperature and relative humidity in the new chamber. It is also concluded that the alarm after 20 minutes does not depend on the conditions of initials temperature and relative humidity.

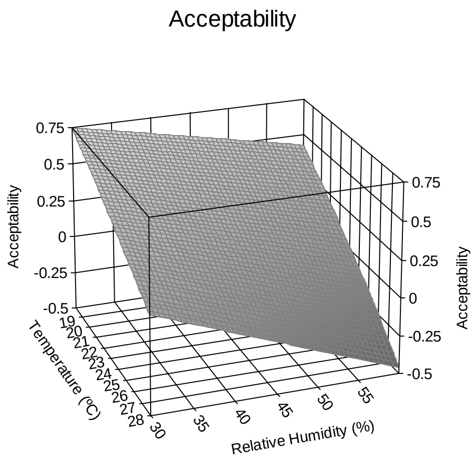
The results show that there is an increasing acceptability with the drop in temperature and relative humidity and that a cooling of the mucous membranes is essential to perceive the air as acceptable, as it demonstrates the influence of the air enthalpy. The results indicated that, for a whole body exposure, there is a linear relationship of the acceptability with the enthalpy, both for clean air as polluted, see Figure 4. It was concluded that there is no difference between the initial acceptability and the acceptability after 20 minutes of exposure. It also follows that the acceptability is independent of the environment conditions that surrounds the individual before entering the camera.

The findings of tests on odours indicate that the intensity of the odour varies little with temperature and relative humidity and that there is some adjustment to smell after about twenty minutes. Berglund and Cain studies (1989) were proved in the absence of adaptation of acceptability in time. It also checks the conclusion of Gunnarsen (1990) when it confirmed adaptation to smell inside after some time.

An important conclusion that has been reached with this review is that it is possible to save energy if you lower the number of air changes, temperature and relative humidity [16-19]. These discussions are ongoing to maintain the PD with the corresponding energy savings. We must remember that cold, very dry air with high pollution causes the same number of dissatisfaction than clean, mild and more humid air. It is interesting to note that if the temperature and elative humidity slightly drop, pollutants emitted by each of the materials (Fang 1996) will be reduced so.

At present, field tests are recommended by the majority of researchers so they can perform characterization of environments according to their varying temperature and relative humidity [20]. This may start the validation of models that simulate these processes by computer and that let implement HVAC systems to reach the better comfort conditions and, at the same time, other objectives like energy saving, materials conservancy or work risk prevention in industrial ambiences[21].

Figure 4: Influence of temperature and relative humidity on the acceptability.



4. Conclusions

Given the varied activities of international involvement in indoors environments it was necessary a deep research report about thermal comfort investigations based on results of scientific research and actual ISO and ASHRAE Standards. Once this research report was done it was concluded the need to develop and test general and local thermal comfort models that let implement HVAC systems to reach the better comfort conditions [22] and, at the same time, other objectives like energy saving [23], materials conservancy or work risk prevention in industrial ambiences.

5. Acknowledgement

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