Humidity and its Impact on Human Comfort and Wellbeing in Occupied Buildings

Humidity Group

of the *HEVAC* Association

HEVAC

Contents:

INTRODUCTION

A controlled and regulated indoor environment is necessary for humans to be comfortable inside buildings. Humans need to have a thermal balance between themselves and the environment they occupy, known as 'Thermal Comfort'. Thermal Comfort directly influences the actual and perceived quality of the indoor environment; it is determined by the effect of the interrelationship between air temperature, relative humidity (RH) and air movement on occupants; together with human metabolic rate and thermal insulation value of clothing that occupants wear.

Air Conditioning – A process of altering the properties of air, primarily temperature and humidity; to more favourable conditions.

The amount of humidity in the air has a direct impact on Thermal Comfort which in turn impacts upon the health and wellbeing of building occupants. Maintaining the level of indoor humidity between 30-70 %rh is essential in spaces that human beings occupy as it allows them to function optimally.

HUMAN THERMAL COMFORT

Thermal Comfort is defined in British Standard BS EN ISO 7730 (1) as: *'that condition of mind which expresses satisfaction with the thermal environment.'*

So the term 'Thermal Comfort' is used to describe an individual person's relationship with their environment and is often simply referred to in terms of whether someone is feeling too hot or too cold. In reality however, Thermal Comfort is very difficult to define in a quantifiable sense because of the need to take into account a range of environmental and personal factors when deciding what will make people feel comfortable.

The environmental factors are determined by the effect of the interrelationship between air temperature, mean radiant temperature, RH, and air movement on the occupants.

Personal factors are age, gender, human metabolic rate, activity level and the thermal insulation values of the clothing they wear.

Women frozen out by office air-con systems designed for male comfort, scientists find.

Indoor climate control systems are based on the resting metabolic rate of an average 40-year-old man, who is likely to feel more comfortable at a lower temperature than women, say scientists.

Studies found that “women tend to be cooler than men in cool conditions” and were “more sensitive than men to fluctuations in the optimum temperature.”

A study found that the neutral temperature for Japanese women was 25.2 °C, whereas it was 3.1 °C lower for European and North American men under the same conditions. Finnish research found that women were “less satisfied with room temperatures, preferred higher room temperatures, and felt both uncomfortably cold and uncomfortably hot more often than men.”

The authors wrote: “Thus, current indoor climate standards may intrinsically misrepresent thermal demand of the female and senior sub-populations.”

This in turn was likely to make office heating and cooling systems less energy efficient than they could be, they added. The authors called for a new system that takes into account gender differences, as well as age and physiological characteristics such as being lean or obese.

http://www.independent.co.uk/news/uk/home-news/women-frozen-out-by-office-air-con-systems-designed-for-male-comfort-scientists-find-10436035.html

The National Oceanic and Atmosphere Administration, Environmental Data and Information Service and National Climate Change Centre (USA) has published a table that relates a range of room air temperatures with a range of relative humidity values and assigns at each value an apparent temperature the occupant would feel. This clearly highlights the relationship between air temperature and RH (%rh).

Apparent Temperature Data

Source National Oceanic and Atmosphere Administration, Environmental Data and Information Service and National Climate Change Centre (USA)

Room °C	% Relative Humidity								
	20	30	40	50	60	70	80	90	100
24	22	22	23	24	24	24	25	26	26
23	20	21	22	22	23	23	24	24	25
22	19	19	20	21	22	22	23	23	24
21	18	18	19	19	20	21	21	22	22
20	17	18	18	19	19	20	21	21	22
19	16	17	17	18	18	19	19	19	20
18	16	16	16	17	17	18	18	18	19
17	14	14	15	16	16	16	17	17	17
16	13	14	14	14	15	15	16	16	16

No change between actual and apparent temperature			
-2	2 °C lower than actual room temperature	1	1 °C higher than actual room temperature
-1	1 °C lower than actual room temperature	2	2 °C higher than actual room temperature

CURRENT LEGISLATION

All workplaces are covered by the *Health and Safety at Work Act 1974 (HSW Act)* (2) plus the amended *Health and Safety at Work Regulations 1992 (MHSWR)* (3). These set out the general duties that building owners have towards employees and members of the public in providing a working environment that is both safe and without risk to health.

The act states that workplaces must be adequately ventilated (regulation 6); it goes on to state that to effectively ventilate a workplace, fresh clean air should be drawn from a source outside and circulated through the building. The ventilation system should remove and dilute warm, humid air and provide air movement, to create a sense of freshness without causing a draught. Humidity and ventilation should be maintained at levels which prevent discomfort or problems of sore eyes.

HSE Guidance note 194 (4) discusses Thermal Comfort and identifies practical ways to achieve workplace health safety and welfare. Thermal Comfort is identified in two particular ways: firstly the environment inside the workplace, and secondly the way the individual interacts with that indoor environment. Indoor humidity is one of six specified influencing environmental variables. The other variables are air temperature, mean radiant temperature, ventilation, air velocity, climatic and seasonal variations in outdoor temperatures, and solar intensity.

PUBLISHED RESEARCH

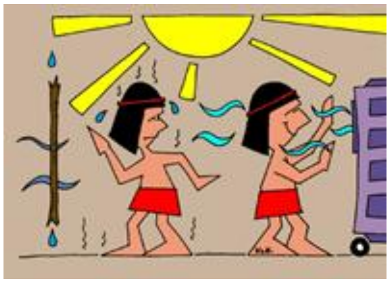
Thermal Comfort

BSRIA Applications Guide AG10/94.1; *Efficient Humidification in Buildings* (5), concluded that Relative Humidity (RH) is an important variable for Thermal Comfort and the well-being of humans. If the air is too dry, respiratory problems coupled with skin and eye irritation can occur. Very high levels of RH can lead to respiratory ailments, thermal discomfort and condensation problems.

Holness (6) considered the interaction between human comfort and indoor air quality (IAQ), in particular the influence of ventilation rate, air circulation and control of humidity. *Toftum and Fanger* (7) in 1999 proposed a model to evaluate the impact of high relative humidity levels on human comfort. More recent studies into the impact of low humidity levels on health and comfort in an office building were reported by *Aizlewood* (8); the combined effects of air temperature, relative humidity and work rate on human stress in hot and humid environments has also been extensively studied (9).

TEWL and the relationship to thermal comfort

TEWL – Transepidermal Water Loss is defined as the quantity of water that passes from inside a body through the epidermal layer to the surrounding atmosphere via diffusion and evaporation processes. This is not the water loss that is associated with sweating but the natural loss of water vapour from the skin.



Evaporative cooling is the physical principle of a reduction in temperature resulting from the Evaporation of a liquid.

Humidity has a direct impact upon the structure and fabric of buildings (mould growth, fabrics and furniture) and the control of RH in buildings is essential for occupant wellbeing. Trying to maintain a Relative Humidity level below 70 %rh is also the main driver for the *2010 Building Regulation Approved Document F: Ventilation* (10). *CIBSE Guides* (11) and *ASHRAE fundamentals Guide* (12).

Human Health

The primary influences of humidity on health are through biological pollutants and their survival in the air (at a temperature of 21°C, influenza survival in the air is lowest at a mid-range 40 %rh to 60 %rh.).

Most infectious diseases spread when pathogens are transmitted through human-to-human contact when droplet nuclei form as a result of sneezing or coughing and are subsequently inhaled by a human receptor. Biological pollutants include pathogens such as bacteria (e.g., Streptococcus, Legionella), viruses (e.g., common cold, flu), and fungi (e.g., Aspergillusfumigatus). Allergic reactions (e.g., asthma, rhinitis) and dust mites are all affected by the amount of humidity in the air. Humidity values less than 50 %rh are fatal to the dust mite. *Baughman, A: Arens, E* (13).

An environment with relative humidity lower than 50 %rh will increase the spreading rate of influenza virus. *Hemmers* (14). More recently, the US National Institute for Occupational Safety and Health has also demonstrated that relative humidity can be a factor in controlling the spread of flu (15).

Studies have shown that an increase in humidity can reduce nose tissue inflammations. It was found that an increase in humidity can reduce the nose irritations of 1 in 6 people *Hashiguchi, N 2007* (16). A study of the effect of relative humidity on nasal mucus has shown that the viscidity reduces by half when relative humidity drops from 100 %rh to 60 %rh.

Sick Building Syndrome

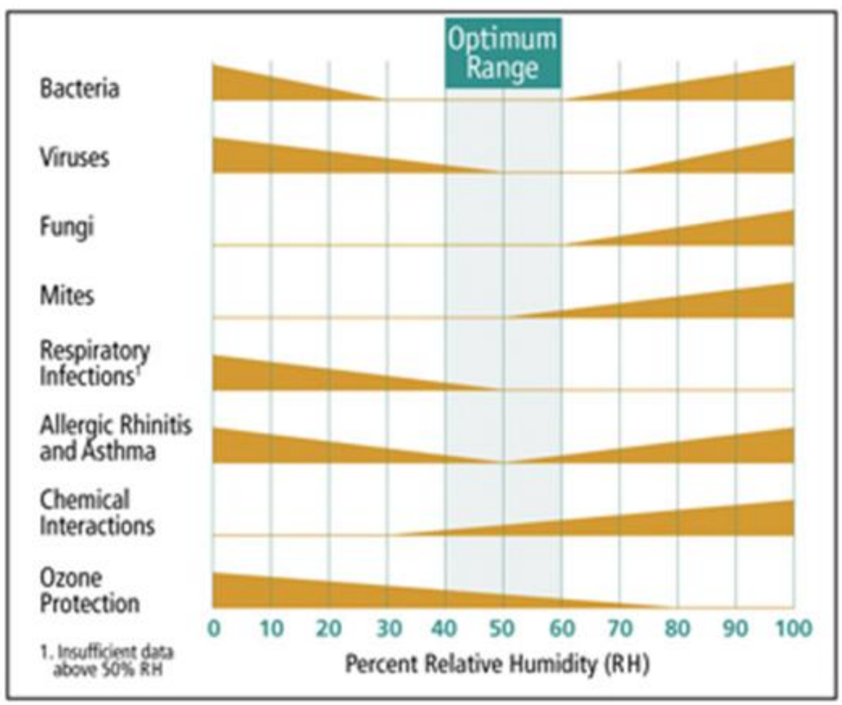
The control of an appropriate thermal environment, therefore, is important for the good health of the building's occupants, in for example, hospitals *Ruey-Lung Hwanga* (17).They found that the general public thought that good control of the thermal environment was only about controlling the air

temperature inside the room. However there were still a lot of people inside such a temperature controlled environment suffering from nose irritations, stuffy and runny nose, eye irritations, cough, tightness in the chest, fatigue, headache and skin irritations.

Such symptoms are called sick building syndrome (SBS) which is affected by relative humidity inside the room, *Arundel, A.V 1986* (18). This is because humidity affects the rate of water evaporation in the air and the balance of energy inside the body and therefore the Thermal Comfort of human beings *L. Harriman et.al 2001*(19).

Research by *Sookchaiya* (20) into the study and development of a temperature and relative humidity control system in hospital buildings in Thailand found that too high and too low RH had direct and indirect effects on the symptoms of SBS

It has also been shown that the RH affects the intensity of chemical pollution in the air by changing the distribution rate of gas from the materials used inside the buildings and the reaction between water and chemicals in the air.



Decrease in bar width indicates a decrease in negative IAQ factors and complaints. (21)

Energy Usage and Humidity Control

Air conditioning typically accounts for more than half of a commercial building's operational energy.

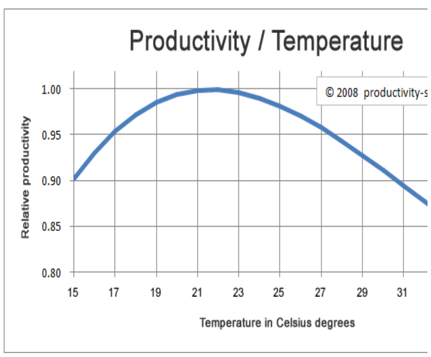
In addition the largest cost for commercial buildings is the salaries of the occupants. In the US, salaries average about $200 per square foot per year; building leases average approximately $20 per square foot per year; and, energy costs average less than $2.00 per square foot per year. Estimates suggest the impacts of poor indoor environmental quality on well-being and productivity equates to a cost of $1,071-$1,211 per person per year. Finally, buildings with optimised indoor environmental quality are valued ~3-7% higher for sale and rental and operating costs are 13-15% lower (Rahman (2015) (22).

Function list and assignment to energy performance classes (section from table 1 of the EN 15232:2007 [D])

	Heating / Cooling control	Ventilation / Air conditioning control	Lighting	Sun protection
A	– Individual room control with communication between controllers – Indoor temperature control of distribution network water temperature – Total interlock between heating and cooling control	– Demand or presence dependent air flow control at room level – Variable set point with load dependant compensation of supply temperature control – Room or exhaust or supply air humidity control	– Automatic daylight control – Automatic occupancy detection manual on / auto off – Automatic occupancy detection manual on / dimmed – Automatic occupancy detection auto on / auto off – Automatic occupancy detection auto on / dimmed	– Combined light/blind/ HVAC control
B	– Individual room control with communication between controllers – Indoor temperature control of distribution network water temperature – Partial interlock between heating and cooling control (dependent on HVAC system)	– Time dependent air flow control at room level – Variable set point with outdoor temperature compensation of supply temperature control – Room or exhaust or supply air humidity control	– Manual daylight control – Automatic occupancy detection manual on / auto off – Automatic occupancy detection manual on / dimmed – Automatic occupancy detection auto on / auto off – Automatic occupancy detection auto on / dimmed	– Motorized operation with automatic blind control
C	– Individual room automatic control by thermostatic valves or electronic controller – Outside temperature compensated control of distribution network water temperature – Partial interlock between heating and cooling control (dependent on HVAC system)	– Time dependent air flow control at room level – Constant set point of supply temperature control – Supply air humidity limitation	– Manual daylight control – Manual on/off switch + additional sweeping extinction signal – Manual on/off switch	– Motorized operation with manual blind control
D	– No automatic control – No control of distribution network water temperature – No interlock between heating and cooling control	– No air flow control at room level – No supply temperature control – No air humidity control	– Manual daylight control – Manual on/off switch + additional sweeping extinction signal – Manual on/off switch	– Manual operation for blinds

Energy usage vs. apparent temperature

Apparent temperature is the general term for the perceived temperature, caused by the combined effects of air temperature, relative humidity and wind speed.



"An indoor humidity level of 30 - 40% is recommended in the winter months; depending on your personal preferences, this may be even higher. The end result is a warmer, more comfortable home and a likely reduction in your energy bills." (23)

Around the world, new legislation is promoting the use of energy efficient technologies. The European Standard EN 15232 ("Energy performance of buildings – Impact of Building Automation, Controls and Building Management") was compiled in conjunction with the Europe-wide implementation of the directive for energy efficiency in buildings (Energy Performance of Buildings Directive EPBD) 2002/91/EG. The standard describes methods for evaluating the influence of building automation and technical building management on the energy consumption of buildings. After a building has been equipped with building automation and control systems, it will be assigned one of these classes. The potential savings for thermal and electrical energy can be calculated for each class based on the building type and building purpose.

CONCLUSIONS

Humidity control has a strong bearing on Thermal Comfort, Indoor Air Quality (IAQ) and eventually on the health and performance of occupants in habitable and public spaces.

Buildings rely on a properly designed ventilation system to provide an adequate supply of cleaner air from outdoors or filtered, recirculated air. Rooms are often designed with specific conditions in mind including temperature, relative humidity, brightness, noise, and air flow. Careful engineering and implementation of building automation and control is the only way to ensure energy efficiency and building operation conditions are met during occupancy, at the lowest possible costs with the least possible impact on the environment.

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