Human Comfort

Section Preview

This section discusses the following topics:

- Factors of human comfort including air temperature, motion and cleanliness, and the relative humidity of the air
- HVAC engineering standards
- Perceptions of comfort

Factors of Human Comfort

As mentioned earlier, the fundamental purpose of HVAC systems is to provide human comfort.

Human comfort and the amount of air conditioning required for a given space is determined by controlling four air factors:

- Air temperature
- Air motion
- Air cleanliness
- Relative humidity of the air

Air Temperature

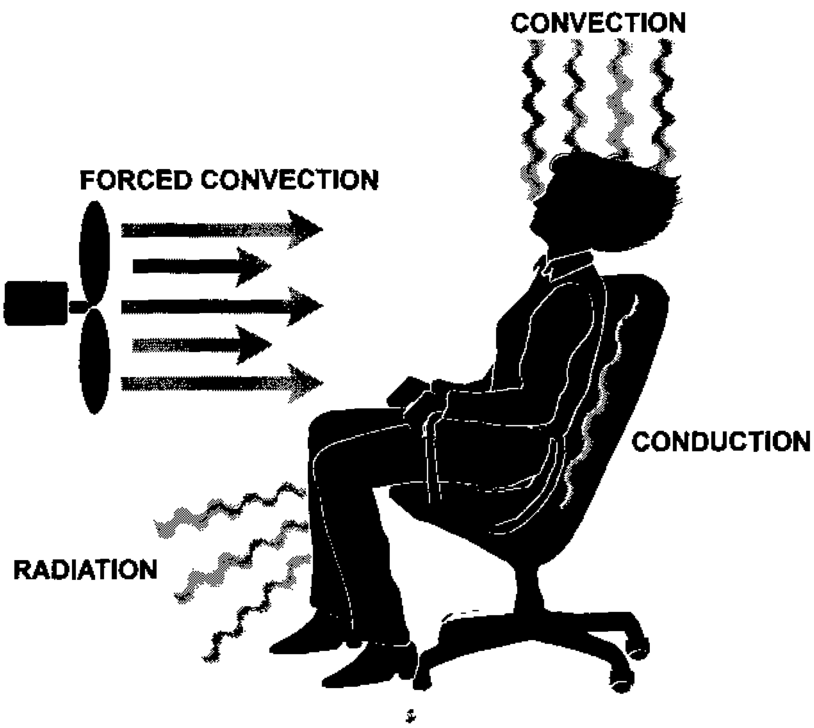
A healthy human body constantly generates more heat than it needs. It disposes of that excess heat through the skin in the three ways we discussed earlier:

- Conduction (when you touch something cooler)
- Convection (to the passing air)
- Radiation (to other objects that are cooler)

If your body can't rid itself of heat fast enough, you perspire. If your body loses too much heat too rapidly, it experiences coldness.

The colder the surrounding ambient temperature, the more heat your body loses.

For energy savings and comfort too, set the thermostat to 65° in cold weather and 78° in warm weather.



Air Motion

The motion of air, measured in feet/minute, also affects our comfort.

- If the air motion is too fast, we experience drafts.
- If the air motion is too slow, we feel smothered and suffocated.

The optimum air motion is between 15 to 25 feet/minute.

Increasing air movement increases the rate of convection and the rate of evaporation. That's why you feel cooler when you sit in front of a fan.

Air Cleanliness

Filtering air in a conditioned space is an important function of the AC system. We normally filter out dust, pollen and other small, unwelcome particles.

There are many kinds of filtering systems. They vary depending on the type of environment and situation.

For system efficiency, filters must be changed when they become dirty. We'll say more on this topic later.

Relative Humidity of the Air

Air contains moisture, and at different times holds different amounts of it.

Relative humidity is a measure of how much moisture the air is actually holding as compared to how much moisture it could hold at any given temperature.

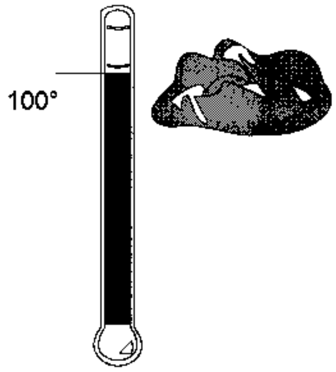
You can see moisture that the air contains in the form of clouds, rain, or fog. Sometimes, you cannot see it, but you certainly feel it when the relative humidity is high—the air feels "muggy." At times, it's so muggy that the moisture actually condenses into droplets on walls or the ceiling.

At other times, there's not enough moisture in the air and you feel too dry. You experience a lot of static electricity and your skin dries out.

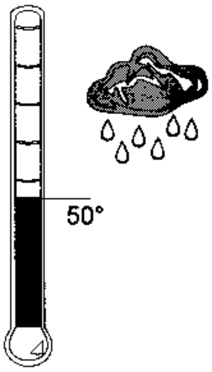
When the relative humidity is 50%, the air could hold twice the water it now holds before it is totally saturated.

Temperature is an important factor in relative humidity.

- As the air temperature increases, the air expands and is able to hold more moisture.
- As the air temperature decreases, the air cools and contracts, reducing the amount of moisture it can hold.



At a higher temperature the air holds more moisture



At a lower temperature the air holds less moisture

If the temperature rises but the amount of moisture in the air stays the same, then the relative humidity is lower (the higher temperature allows the air to hold more moisture, so the percentage of moisture in the air compared to what it can hold is lower).

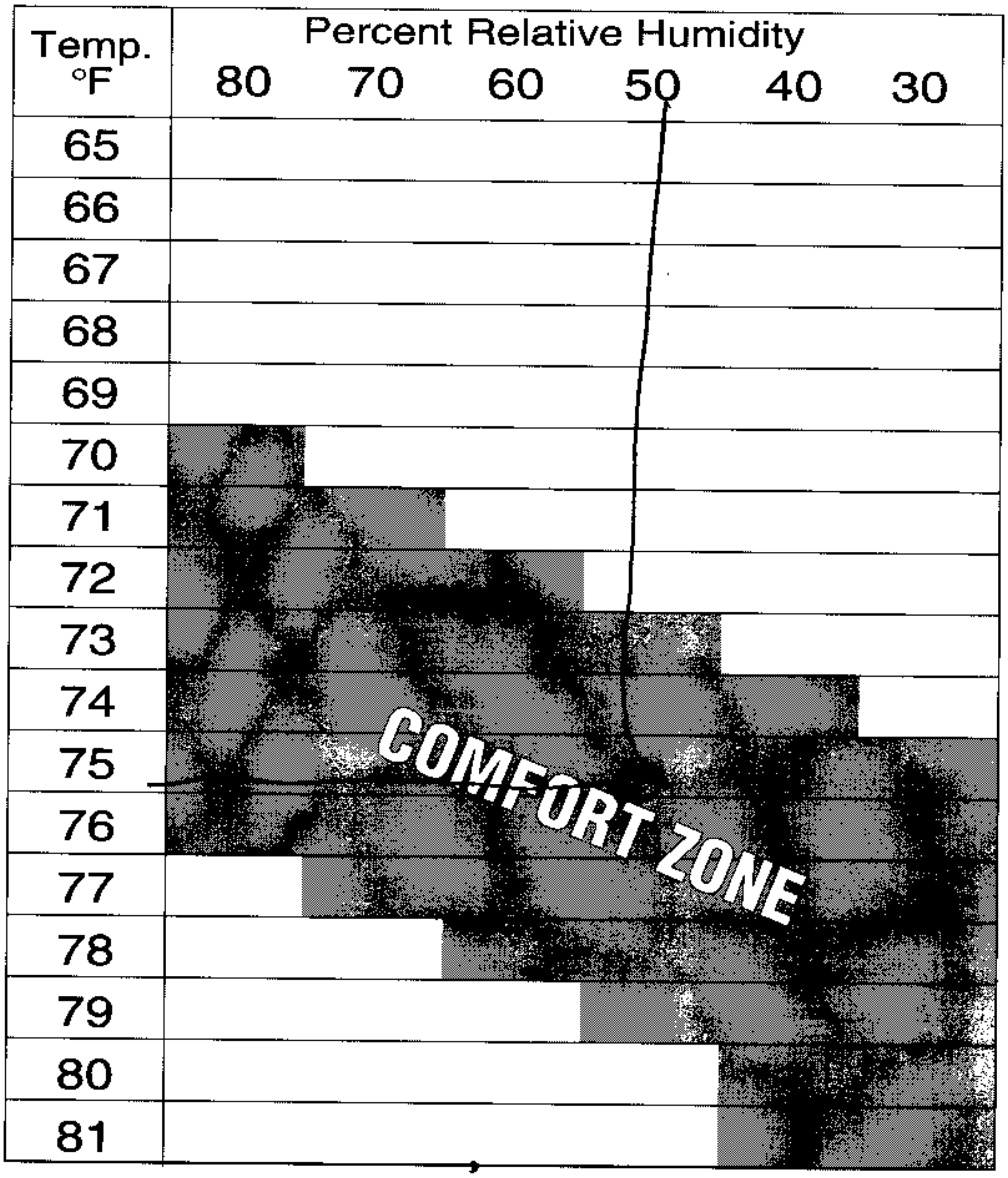
If the temperature falls but the amount of moisture in the air remains the same, then the relative humidity increases.

The temperature at which the relative humidity is 100% is called the **dew point**. This is the point where the air can hold no more water, and is saturated. Any lower temperature than the dew point will cause moisture to condense out of the air in the form of droplets or fog.

To see the effect of lowering the air temperature, put a glass of ice on a table. As the heat transfers from the warmer air to the ice, the air temperature lowers around the glass. When it gets low enough, beads of water begin to form on the glass. The water vapor condenses out of the air because we have reduced the air temperature below the dew point.

Controlling the amount of moisture in the air is very important for comfort. Aside from mugginess or static electricity, the amount of moisture in the air also affects the rate of evaporation of perspiration. A low relative humidity allows the body to rid itself of more heat more quickly through evaporation because the air can absorb more moisture.

The chart below shows the temperature and humidity ranges where 70% of test subjects said they were comfortable. Keep in mind that no one condition will satisfy everybody.



Climate control comfort guidelines

HVAC Engineering Standards

Air conditioning systems are supposed to make people more comfortable. But in actuality, many systems fall short of this goal.

Complaints about offices being too hot or too cold head the list in the work environment; especially complaints about it being too cold in the summer.

Most air conditioning systems have a poor overall performance record. But there are techniques that can substantially reduce energy demand for space cooling while simultaneously making people more comfortable, healthy, and productive.

There are engineering standards for air conditioning system design and how the design should meet human comfort requirements. Indoor design conditions, including indoor design temperature and humidity conditions for general comfort applications, must be in accordance with the comfort criteria established in ANSI/ASHRAE Standard 55-2004, “Thermal Environmental Conditions for Human Occupancy.”

Standard 55-2004, "Thermal Environmental Conditions for Human Occupancy," is a revision of Standard 55-1992. The standard sets forth the conditions at which a specified amount of the occupants of a building will find the environment “thermally acceptable.”

ANSI is the American National Standards Institute and ASHRAE the American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.

Standard 55-2004 takes into account many factors including:

- Temperature
- Humidity
- Metabolic activity
- Clothing and furniture
- Radiant temperature
- Air movement

Perceptions of Comfort

Often meeting HVAC standards is difficult because:

- Variation between individuals and their different perceptions of comfort
- Each individual feels different at different times and will have substantial variation in their metabolic rate
- AC systems are allowed a range of comfort conditions
- The environment itself changes (dynamic comfort conditions)

Variation Between Individuals

HVAC systems can be designed so that different building areas or "zones" are handled separately. This means that inevitably some people will be comfortable and others will not be comfortable—especially considering people wear different types of clothing and work in areas that receive different airspeed levels.

But with individual climate control, especially control of airspeed, human diversity becomes an advantage: space cooling can be concentrated on those who need it more, and in the forms they find most helpful, without overcooling people who need it less.

Variation Over Time

The metabolic rate of each individual also will vary on different days and at different times of the day. The metabolic rate and how a person feels at a given moment will vary according to diet, mood, stress, state of health, etc.

Allowing individual control of local climate lets occupants constantly adjust conditions to meet changing needs. In contrast are the one-size-fits-all settings that can result in varying degrees of discomfort.

Since people's needs for comfort do not all vary in the same pattern, this can again be expected to save energy (through greater load diversity) while improving comfort and control.

Systems Are Allowed a Range Of Comfort Conditions

The human body has thermal mass, and heat transfer is a gradual process, not instantaneous.

ANSI/ASHRAE Standard 55-1992 specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants within a space. The environmental factors addressed are temperature, thermal radiation, humidity, and air speed; the personal factors are those of activity and clothing. (Standard 55-1992 has been replaced by Standard 55-2004.)

Standard 55-1992 permits "operative" temperature fluctuations in average conditioned space within a "peak-to-peak" range of 2° F or less. Larger variations of operative temperature may not exceed a rate of 4° F per hour.

Slow drifting and "ramping" of operative temperature are also permissible so long as it "does not extend beyond the comfort zone by more than . . . 1° F and for longer than one hour."

Standard 55-1992 has a range of temperature recommendations for summer and winter temperatures.

Relative Humidity	Winter temperatures (deg. F)	Summer Temperatures (deg. F)
30%	68.5 – 76	74 – 80
40%	68.5 – 75.5	73.5 – 79.5
50%	68.5 – 74.5	73 – 79
60%	68 – 74	72.5 – 78

METABOLIC RATE

ASHRAE Temperature Recommendations

Dynamic Comfort Conditions

People thrive on a varying, stimulus-rich environment. A subject that deserves some study is the idea of making the comfort conditions dynamic. That is, the air conditioning system might be controlled to simulate the natural changing pattern of environmental conditions.

If this idea is applied, comfort would become not just an engineered product but a form of art.

Metabolic Rate

Comfort conditions are highly sensitive to metabolic rate. As examples, a sedentary person will be comfortable at 75° F at an airspeed of 30 feet per minute and relative humidity of 50%. People who operate at vigorous levels of activity will typically prefer much cooler temperature—from 10 to 15° F cooler.

Physiological Considerations for Human Comfort

Depending on the level of activity, the human body can generate from 300 to 3,000 BTU/hour of heat. Heat is generated as part of the natural metabolic processes of the body.

However, body temperature must be maintained in a narrow range in order stay comfortable—a temperature change of only a few degrees in the human body can potentially present serious danger due to heat or cold stress.

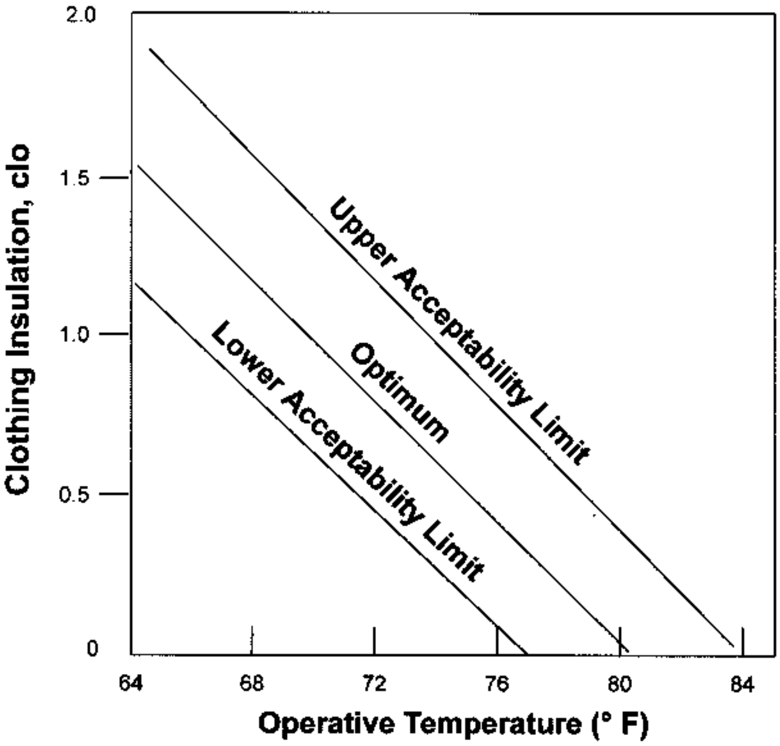
In order to maintain a comfortable body temperature, the heat generated and heat dissipated from the body must remain in balance.

Physiologically, the body automatically regulates internal temperature by increasing or decreasing the flow of blood to the skin.

- To warm the body up, the flow of blood is decreased so that more heat is retained. If the decrease in blood flow is not sufficient, heat must be generated, either by voluntary muscular activity or involuntary muscular activity (shivering).
- To cool the body down, the blood vessels in the skin are dilated to increase blood flow. This increases the skin temperature and the rate of heat rejected from the body. If the dilation is not sufficient, then sweating will occur, which cools the skin through evaporation.

Clothing

The comfort equation and the ASHRAE standard show major sensitivity of comfort to clothing—a slope of about 11.3° F per clo (insulating value) at an airspeed of about 20 ft/min and activity levels $\leq$ 1.2 met (metabolic rate)—as shown in the figure below.



Sensitivity of ASHRAE comfort conditions to clothing

Standard 55-2004 takes into account that because it is not possible to dictate the metabolic rate of occupants, and because of differences in the amount of clothing occupants may choose to wear, operating setpoints are not mandated by the standard.

Sensitivity Of ASHRAE Comfort Conditions To Clothing		
Clothing	**Insulating Value (clo)**	**Temperature Comfort Range***
Heavy two-piece business suit and accessories	1.0 clo	70.2° optimum, up to 73.3° F
Light slacks and a short-sleeved shirt or blouse	0.5 clo	72.5° optimum up to 76.3° F
Shorts, open-neck short-sleeved shirt or blouse, light socks, and sandals	0.3 clo	74.8° optimum, up to 78.6° F

* based on ASHRAE comfort optimum

The data in the table demonstrates how the clothing you wear has an impact on the optimum comfortable air temperature. The figures are based on the ASHRAE comfort optimum (with 50% relative humidity and 30 ft/min airspeed). The first temperature is the optimum and the second is the temperature upper limit at which 80% of people are satisfied.

Even small pieces of clothing can add up: in general terms, a warm shirt, instead of a cool knit shirt, or a T-shirt instead of an undershirt, adds 0.03 clo.

Just wearing a necktie adds some 5% to clo value, which adds about 0.5° F to cooling requirements. This increases cooling energy requirements about 0.4 to 0.8%. This requirement adds a whole-system capital cost on the order of $43, not counting the extra fuel and goes to show that a corporate dress code requiring formal business attire can cost the company around 10-20% extra in summer space-conditioning energy and capital costs!

Radiant Temperature

With moderate airflow, the mean radiant temperatures below around 120° F can be averaged with air temperature to obtain the effective drybulb temperature perceived by the body.

The inner surface of a sunlit pane of heat-absorbing office glass, for example, typically has a radiant temperature around 120-150° F, enough to cause strong radiant discomfort several yards away.

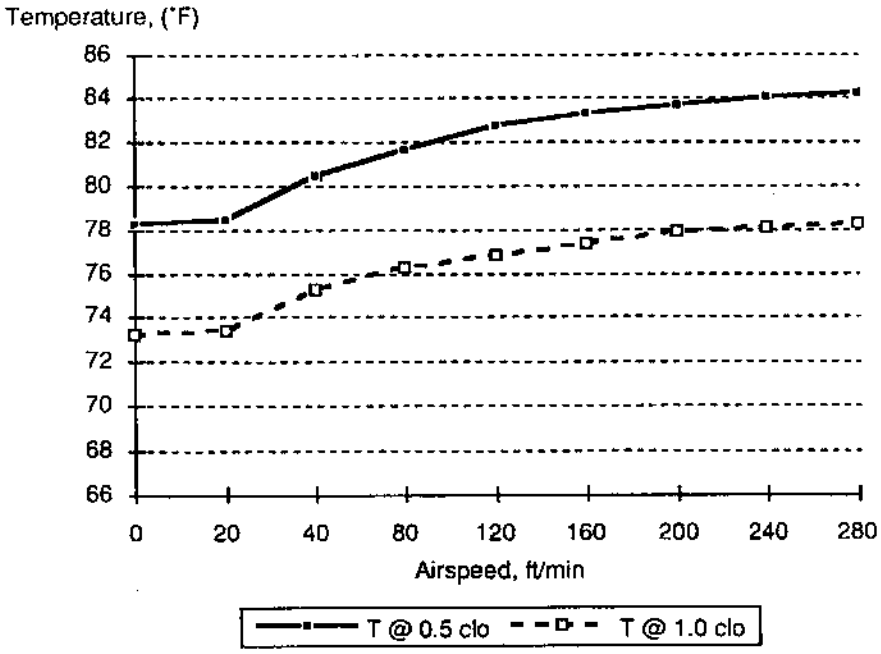
The change in air temperature needed to offset high radiant temperature is strongly sensitive to air movement. That is why so many people sitting next to a window hot from radiated heat use portable fans.

Air Movement

In warm air at high humidity, both with convection and evaporative cooling make air movement a powerful way to increase comfort.

Because of the evaporative cooling, air movement can cool the skin, so long as evaporation cools the skin more than the hot air heats it.

For example, at 300 ft/min airflow, even at air temperatures up to 90° F, your skin will feel cooler as long as relative humidity does not exceed 50%. Conversely, the same airflow provides comfort at 83° F and 100% relative humidity.



Optimal comfort temperatures as a function of airspeed

Ceiling fans, in spite of their low airspeeds, provide effective cooling because their turbulent airflow is especially efficient in increasing heat transfer.

Measurements taken in the flow from ceiling fans found that people are just as comfortable under a ceiling fan in 85° F air as they are without the fan in 76° F air. That remarkable 9° F extension of the comfort envelope is an important tool in energy-efficient space cooling.