Chapter

2

Thermal Comfort

Temperature and temperature variations govern much of our daily lives. Shelter, clothing, heating, air conditioning, and building insulation influence the thermal forces that determine a person's state of comfort. It is this idea of "thermal comfort" that designers, builders, and architects attempt to provide by active or passive means when creating shelter.

Thermal comfort, ever a vague and ambiguous term given the varying nature of the human condition, has been described as a feeling of well-being, an absence of discomfort, or a state of mind that is satisfied with the thermal environment. The body's network of sensory organs, such as the eyes, ears, nose, tactile sensors, heat sensors, and brain all contribute to the physiologic and psychological awareness of thermal responses.

Thermoregulation

As my college professor once said, "Human bodies are like a bunch of little furnaces running around." Truer words were never spoken, since each human body generates heat. As warm-blooded mammals, humans produce energy by metabolizing food, with most of this energy taking the form of heat. Metabolic heat is produced by the body all the time, mainly as a result of muscular activity, although almost all bodily functions produce some heat. It is no secret that the more active we are, the more heat we produce.[1]

Heat is transported around the body by the blood. To balance the metabolic input, heat is lost continually to the environment through the skin and through the surfaces of the lungs. Subsequently, human thermal comfort is also determined by the body's ability to dissipate the heat and moisture that are produced continuously by metabolic action.

Heat is measured in British thermal units (a Btu is the quantity of heat required to raise one pound of water one degree Fahrenheit). For men of average size, seated and doing light work, the metabolic rate is about 450 Btu/h. Women under similar circumstances generate about 385 Btu/h. For a 155-lb man, seated and doing moderate to heavy work, the rate ranges from 650 to 800 Btu/h; standing and walking about while doing moderately heavy work will raise the rate to 1000 Btu/h, whereas the hardest sustained work will result in a metabolic rate of 2000 to 2400 Btu/h.

Thermal comfort is said to be attained when the environment surrounding the individual is in a state of equilibrium; i.e., the heat and moisture produced by the body are removed at the rate at which they are being produced. One method in which the human body maintains thermal equilibrium with its environment is by means of physiologic thermoregulation. For example, in situations of prolonged sweating, skin wetness slowly increases with time because of accumulating salt on the skin. The increasing salt occurs because the water in perspiration evaporates, while the dissolved materials, principally sodium chloride, remain on the surface. It is also thought that part of the relief that bathing brings after a warm day or strenuous activity is that by cleaning the skin, the salt is removed and the perspiration can evaporate more efficiently with reduced skin wetness. Another method of physiologic thermoregulation is shivering. The muscle tensions that cause shivering create a 300 percent increase in heat production, while the body also tries to cut heat loss by limiting blood flow to the skin and extremities.[1]

While some heat is removed through breathing, heat loss through the skin is by far the major path. Cold receptors in the skin signal the brain if the temperature on the skin drops at a rate faster than 0.5°F (0.25°C) per minute. This process allows people to adapt to indoor and outdoor climates by means of behavioral adjustments such as light or heavy clothing, low- or high-speed fans, open or closed windows, etc. An event as mundane as a cool draft of air can change local air temperatures by 2°F (1°C) in a matter of seconds.

Humidity

Humidity affects comfort in a number of ways, both directly and indirectly. The evaporation of water from mucous and sweating surfaces and its diffusion through the skin affect the energy balance and subsequently body temperatures and thermal sensations. When evaporation processes of the skin are compromised or enhanced, skin temperatures change, which is directly sensed by the temperature sensors of the skin. For example, a 30 percent change in relative humidity has the same effect on thermal balance and thermal sensation as a 2°F (1°C) change in temperature with regard to a sedentary person.

Low humidity, or dry air, absorbs moisture from the skin at a rapid rate and produces a chilling effect that can only be offset by increasing air temperature. Dry air also makes fabrics feel smoother and more pleasant, and the air is perceived to be fresher, less stale, and more acceptable. At a given temperature, decreased humidity results in occupants feeling cooler, drier, and more comfortable, but low humidity also can adversely affect comfort and health. Dry nose, throat, eyes, skin, and other mucous surfaces typically occur in low-humidity conditions, usually when the dew point is less than 32°F (0°C). Excessive drying of the skin can even lead to lesions, skin roughness, and discomfort, and impair the skin's protective functions. Dusty environments can further exacerbate low-humidity dry-skin conditions.[1]

On the other hand, high humidity helps our bodies retain heat. In warm conditions, however, thermal discomfort increases with humidity. The discomfort appears linked with skin moisture, as persons rarely judge themselves comfortable in situations where skin wetness is above 25 percent.[1] The discomfort associated with skin moisture could be due, in part, to friction between skin and clothing. When fabrics ranging from rough burlap to wool, cotton, polyester, and smooth silk are pulled across the skin, the measured pull force increases with humidity and perspiration, as does the fabric's perceived texture or roughness.

Thermal comfort is also directly related to the manner in which heat flows through or about building materials, whether by means of convection, radiation, or conduction. While convection may be most noticeable in the form of a breeze or draft, radiation may seem to cause more dramatic comfort variations. Standing next to a large window is an obvious example. These concepts will be discussed further in Chap. 3.

ASHRAE Standard 55

As mentioned earlier, occupant complaints of discomfort in buildings may be caused by uncomfortable temperatures or extreme humidity levels. In 1966, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) created a standard to quantify thermal comfort. Entitled ASHRAE Standard 55-1966, "Thermal Environmental Conditions for Human Occupancy," this document introduced a definition for thermal comfort that states: "Thermal comfort is that condition of mind that expresses satisfaction with the thermal environment." Standard 55 specified the appropriate environment that would lead to thermal comfort for indoor inhabitants of building spaces. Based on summer and winter temperatures with indoor relative humidity as the variable, the 1992 edition of ASHRAE Standard 55 specifies that the optimal comfort range for indoor relative humidity is between 30 and 60 percent. The standard also specifies that to decrease the possibility of discomfort due to low humidity, dew-point temperature in occupied spaces should not be less than 37°F (3°C).[1]

The upper range of the comfort zone for summer use will be tolerable for most lightly clothed adults until the relative humidity rises above 60 to 65 percent. At that condition, discomfort will be experienced by many building occupants because of their inability to dissipate metabolic moisture. Increases in air velocity are beneficial under these conditions, but velocities above about 70 ft/min generally will result in unpleasant working conditions because of drafts, blowing papers, and so on.[2]

Conclusion

Comfort seems to occur when body temperatures are maintained with the minimum of physiologic regulatory effort.[1] Thermal sensation depends on body temperature, which in turn depends on thermal balance and the effects of environmental factors (temperature, radiation, air motion, and humidity), as well as on personal factors such as an individual's metabolism and clothing selection. Skin moisture, physiologic processes, and skin and internal body temperatures all contribute to the state of thermal comfort. Although many of these factors are constantly in flux, the proper use of insulation, placement of vapor barriers, and understanding of heat transfer will contribute to providing an environment conducive to thermal comfort within the residence.

Appendix

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References

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