University of Diyala
College of Engineering
Mechanical Department

Air Conditioning

6-HUMAN AND ENVIRONMENT

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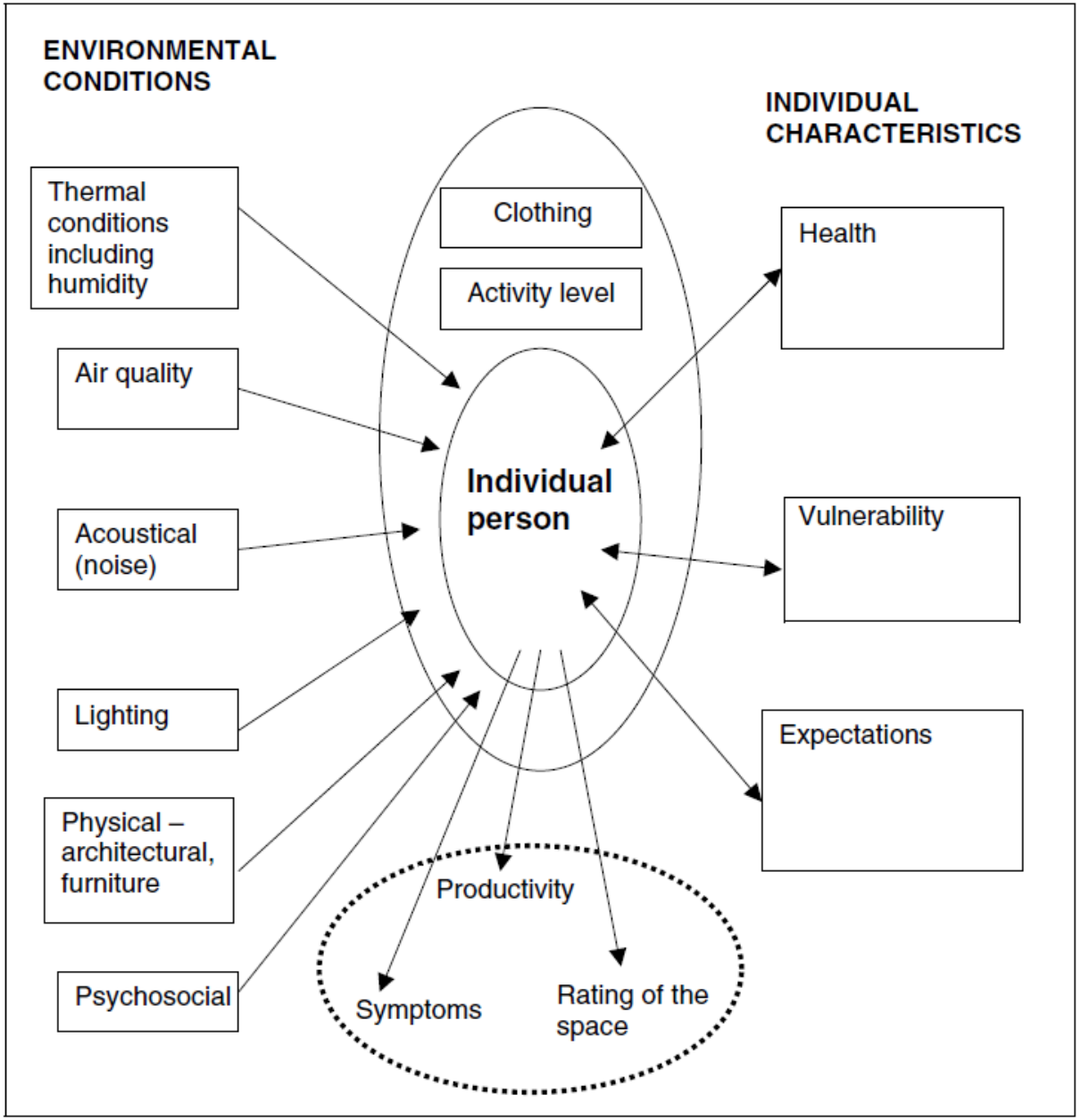
A principal purpose of HVAC is to provide conditions for human comfort, "**that condition of mind that expresses satisfaction with the thermal environment**" (ASHRAE Standard 55).
This definition leaves open what is meant by "**condition of mind**" or "**satisfaction**," but it correctly emphasizes that judgment of comfort is a **cognitive** process involving many inputs influenced by **physical, physiological, psychological, and other processes.**

"**Provide a comfortable environment for the occupants**" sounds like a simple objective, until you start to consider the variety of factors that influence the comfort of an individual.

Air Conditioning

Human and Environment

1. Attributes of the space
2. Characteristics of the individual
3. Clothing and activity of the individual



1. Attributes of the space

Six attributes of the space influence comfort: **thermal, air quality, acoustical, lighting, physical, and psychosocial.**

a. Thermal conditions

include more than simply the air temperature. If the air speed is very high, the space will be considered drafty. If there is no air movement, occupants may consider the space 'stuffy'. The air velocity in a mechanically conditioned space is largely controlled by the design of the system. On the other hand, suppose the occupants are seated by a large unshaded window. If the air temperature stays constant, they will feel very warm when the sun is shining on them and cooler when clouds hide the sun.

b. The air quality

in a space is affected by pollution from the occupants and other contents of the space. This pollution is reduced by the amount of outside air brought into the space to dilute the pollutants.

Densely occupied spaces, like movie theatres, and heavy polluting activities, such as cooking, require a much higher amount of outside air than an office building or a residence.

c. The acoustical

environment may be affected by outside traffic noise, other occupants, equipment, and the HVAC system. A designer may have to be very careful to design a virtually silent system for a recording studio. On the other hand, the design for a noisy workshop may not require any acoustical design consideration.

d. The lighting

Lighting influences the HVAC design, since all lights give off heat. The lighting also influences the occupants' perception of comfort. If the lights are much too bright, the occupants may feel uncomfortable.

e. The physical aspects

The physical aspects of the space that have an influence on the occupants include both the architectural design aspects of the space, and the interior design.

Issues like chair comfort, the height of computer keyboards, or reflections off computer screens have no relation to the HVAC design, however they may affect how occupants perceive the overall comfort of the space.

f. The psychosocial situation

The interaction between people in the space, is not a design issue but can create strong feelings about the comfort of the space.

2. Characteristics of the Individual

All people bring with them **health, vulnerabilities** and **expectations.** Their health may be excellent and they may not even notice the draft from the air conditioning. If the occupants are patients in a doctor's waiting room, they could perceive a cold draft as very uncomfortable and distressing.

The occupants can also vary in **vulnerability**. For example, cool floors will likely not affect an active adult who is wearing shoes. The same floor may be uncomfortably cold for the baby who is crawling around on it.

The occupants bring their **expectations.** When we enter a prestigious hotel, we expect it to be comfortable. When we enter an air-conditioned building in summer, we expect it to be cool. The expectations may be based on previous experience in the space or based on the visual perception of the space. For example, when you enter the changing room in the gym, you expect it to be smelly, and your expectations make you more tolerant of the reality.

3. Clothing and Activity

The third group of factors influencing comfort is the amount of clothing and the activity level of the individual. If we are wearing light clothing, the space needs to be warmer for comfort than if we are heavily clothed.

Similarly, when we are involved in strenuous activity, we generate considerable body heat and are comfortable with a lower space temperature.

In the summer, in many business offices, managers wear suits with shirts and jackets while staff members may wear light clothing. The same space may be thermally comfortable to one group and uncomfortable to the other.

Thermal comfort

There are seven factors affecting the thermal comfort:

- Personal

1. Activity level
2. Clothing

- Individual Characteristics

3. Expectation

- Environmental Conditions

4. Air temperature
5. Radiant temperature
6. Humidity
7. Air speed

1. Activity Level

The human body continuously produces heat through a process call "**metabolism**." This heat must be emitted from the body to maintain a fairly constant core temperature, and ideally, a comfortable skin temperature. We produce heat at a minimum rate when we sleep. As activity increases, from sitting to walking to running, so the metabolic heat produced increases. The standard measure of activity level is the "met." One met is the metabolic rate (heat output per unit area of skin) for an individual who is seated and at rest.

$$1 \text{ Met} = 58.2\ W/m^2$$

Typical activity levels and the corresponding met values are shown in table 4.2

2. Clothing

In occupied spaces, clothing acts as an **insulator**, slowing the heat loss from the body. If you are wearing clothing that is an effective insulator, you can withstand, and feel comfortable in lower temperatures.

Due to the large variety of materials, weights, and weave of fabrics, clothing estimates are just rough estimates. Each article has an insulating value, unit “clo.”

Typical values for clothing ensembles are shown in **table**. All include shoes, socks, and light underwear. The comfortable conditions varies between 0.5 clo and 1.0 clo.

As you can see from table, **0.5 clo** is **very light clothing**, and **1.0 clo** is **heavy indoor clothing**.

Ensemble Description	clo*
Trouser, short sleeve shirt	0.57
Knee-length skirt, short-sleeve shirt (sandals)	0.54
Trousers, long-sleeved shirt, suit jacket	0.96
Knee-length skirt, long-sleeved shirt, half slip, panty hose, long-sleeved sweater	1.10
Long-sleeved coveralls, T-shirt	0.72

3. Occupants' Expectations

People's expectations affect their perception of comfort in a building. Consider the following three scenarios that all occur on a very hot day:

- A person walks into an air-conditioned office building. The person expects the building to be thermally comfortable.
- A person walks into a prestigious hotel. The person expects it to be cool, regardless of the outside temperature.
- A person walks into an economical apartment building with obvious natural ventilation and open windows. The person has lower expectations for a cool environment. The person anticipates, even hopes, that it will be cooler inside, but not to the same extent as the air-conditioned office building or the hotel.

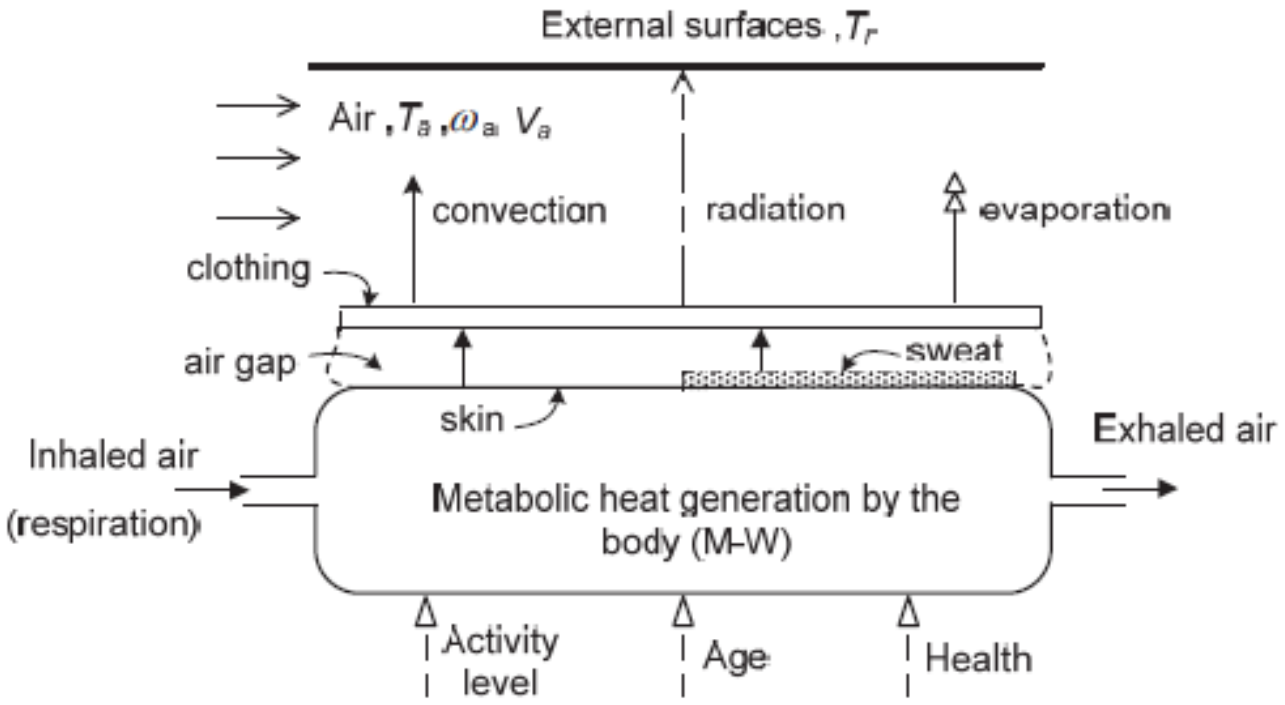
Human body methods for heat transfer

Conduction, convection evaporation and radiation

Heat balance for human body:

$$M\text{-}W=E\pm R\pm C\pm S$$

M=Metabolism rate
W=work
E=evaporation
R=Radiation
C=convection
S=storage



- Air temperature
- Radiant temperature
- Humidity
- Air speed

Heat gain from people

Heat gain from people can be classified as sensible (R+C) and latent (E) as listed in table 4.3.

Typical heat and moisture release rates by people engaged in different activities are given in Table 4.3 at t_d=25.5C. The corrected values take in consideration women and children.

q_t for women = 0.85 q_t for men

$q_t\ for\ child = 0.75\ q_t\ for\ men$

$q_s\ decreases\ by$ 8% $while\ q_L\ increases\ be$ 8% at t_d= 26.6C

$$Sensible\ load = No.\ q_s\ (from\ table\ 4.3)\ CLF(from\ table 4.4)$$

$$Latent\ load = No.\ q_L\ (from\ table\ 4.3)$$

$$Total\ load = No.\ q_t\ (from\ table\ 4.3)$$

CLF=1 when the system not working along the day (shut down at night) and in meeting rooms, theatres and cinemas etc.

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Ex1// Compute the heat gain in a building at 12:00, 14:00 AND 16:00 generated from four people working light work (printing) in an office from 9:00 AM to 17:00 PM if the office temperature is 25.5C.

Ex2// Educational hall for 100 students at 25.5C and 50% relative humidity. Find the sensible, latent and total heat gain from students.

Ex3// Find heat gain from workshop workers if the temperature was 26.6C and the relative humidity 40% for light table work. Compute the amount of generated vapor that should be removed by the cooling coil.

4. Air Temperature

When we are referring to air temperature in the context of thermal comfort, we are talking about the temperature in the space where the person is located. This temperature can vary from head to toe and can vary with time.

5. Radiant Temperature

Radiant heat is heat that is transmitted from a hotter body to a cooler body with no effect on the intervening space. An example of radiant heat transfer occurs when the sun is shining on you. In an occupied space, the floor, walls and ceiling may be at a temperature that is very close to the air temperature. For internal spaces, where the temperature of the walls, floor and ceiling are almost the same as the air temperature, the radiant temperature will be constant in all directions and virtually the same as the air temperature.

When a person is sitting close to a large window on a cold, cloudy, winter day, the average radiant temperature may be significantly lower than the air temperature. Similarly, in spaces with radiant floors or other forms of radiant heating, the average radiant temperature will be above the air temperature during the heating season.

6. Humidity

Low humidity: For some people, low humidity can cause specific problems, like dry skin, dry eyes, and static electricity. However, low humidity does not generally cause thermal discomfort. **Design Standard** does not define minimum humidity as an issue of thermal discomfort, nor does it address those individuals who have severe responses to low humidity.

High humidity: Design Standard does define the maximum humidity ratio for comfort at 0.012 kg/kg which is also 12 g/kg. This level of moisture in the air can also cause serious mold problems in the building and to its contents, since it is equivalent to 100% relative humidity at 17 C.

7. Air Speed

The higher the air speed over a person's body, the greater the cooling effect. Air velocity that exceeds 0.2 (m/s), or cool temperatures combined with any air movement, may cause **discomfort**.

Drafts are most noticeable when they blow across the feet and/or the head level, because individuals tend to have less protection from clothing in these areas of their body.

Reference:

- Fundamentals of HVAC Systems SI Edition by Robert McDowall
- مبادئ هندسة تكييف الهواء والتثليج د. خالد احمد الجودي
- Principles of Heating, Ventilation and Air Conditioning with Worked Examples by Nihal E Wijeysundera

Thank you very much