HVAC - Concepts and Fundamentals

An Online Continuing Education Course for Engineers

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HVAC Concepts and Fundamentals

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HVAC CONCEPTS & DEFINITIONS

HVAC (pronounced either "H-V-A-C" or, occasionally, "*H-vak*") is an acronym that stands for "heating, ventilation and air conditioning". HVAC sometimes referred to as climate control is a process of treating air to control its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space. If the primary function of the system is to satisfy the comfort requirements of the occupants of the conditioned space, the process is referred to as comfort air conditioning. If the primary function is other than comfort, it is identified as process air conditioning.

HVAC systems are also important to occupants' health, because a well-regulated and maintained system will keep spaces free from mold and other harmful organisms. The term ventilation is applied to processes that supply air to or remove air from a space by natural or mechanical means. Such air may or may not be conditioned.

An air conditioning system has to handle a large variety of energy inputs and outputs in and out of the building where it is used. The efficiency of the system is essential to maintain proper energy balance. If that is not the case, the cost of operating an air conditioning system will escalate. The system will operate properly if well maintained and operated (assumption was that it was properly designed in the first place, however, should sizing be a problem, even a relatively costly redesign might prove financially beneficial in a long run).

The HVAC industry had been historically regulated by the manufacturers of HVAC equipment, but Regulating and Standards organizations such as ASHRAE, SMACNA, ARI, ACCA, Uniform Mechanical Code, International Building Code, and AMCA have been established to support the industry and encourage high standards and achievement.

Course Sections

The course consists of five sections that describe the fundamental applications of thermodynamics, psychrometrics and heat transfer in HVAC applications.

SECTION #1	Thermal Comfort – describes the considerations of human comfort, variables affecting thermal comfort, and related terminology such as mean radiant temperature, wind chill factor, heat index, operative temperature, effective temperature and comfort zone.
SECTION # 2	Psychrometrics - Describes how to read seven terms on psychrometric charts: dry-bulb temperature, wet-bulb temperature, dew-point temperature, relative humidity, humidity ratio, specific enthalpy and specific volume. It also describes four air-conditioning processes: viz. mixing; sensible cooling and heating; cooling with dehumidification; and humidification.
SECTION # 3	Modes of Heat Transfer – Describes heat flow through solids and air. This section also includes the terminology and relationships between conductivity, conductance, resistivity, U-factors, etc.
SECTION # 4	Heat Gain and Heat Loss in Building – Includes heat loss/gain calculation procedure, basic concepts and methods to determine cooling loads, effects of windows, walls, roofs and partitions on loads, basic types of internal loads, how to find and use local climate data and effects of air infiltration and ventilation.
SECTION # 5	Annual Energy Use Calculations – Describes the concept of balance point temperature and heating and cooling degree days in determining annual energy costs.

SECTION -1 THERMAL COMFORT

The prime requirement in respect of the indoor climate in a building is that room temperature should be at a comfortable level, regardless of the weather conditions outside. In addition, the indoor air must be acceptably clean, the lighting and acoustic conditions must be good, etc.

Thermal comfort can be defined as a subjective response, or state of mind, when a person expresses satisfaction with the surrounding environment (ASHRAE Standard 55). The environment must provide light, air, and thermal comfort. Proper acoustics and hygiene are also important for physical comfort. While it may be partially influenced by a variety of contextual and cultural factors, a person's sense of thermal comfort is primarily a result of the body's heat exchange with the environment. This is influenced by four parameters that constitute the thermal environment (air temperature, radiant temperature, humidity and air speed), and two personal parameters (clothing and activity level, or metabolic rate).

HVAC and Thermal Comfort

The basic purpose of an HVAC system is to provide interior thermal conditions that a majority of occupants will find acceptable. Occasionally, this may simply require that air be moved at an adequate velocity to enhance convective cooling and evaporation from the skin. Much more commonly, however, providing for occupant comfort will require that an HVAC system add or remove heat to or from building spaces. In addition, it is normally necessary for moisture to be removed from spaces during the summer, and sometimes moisture will need to be added during the winter. The heat and moisture control functions of HVAC systems provide the foundation for key system components. The additional functions of air circulation and air quality control establish further component requirements. In specific building situations, supplemental functions, such as controlling smoke from fires or providing background noise for acoustic privacy, may be imposed on an HVAC system, along with a potential need for additional components. In order to explain how thermal interactions affect human comfort, it is first necessary to define heat and temperature.

Heat and temperature

Heat: Heat may be defined as energy in transit from a high-temperature object to a lower-temperature object. This heat transfer may occur by the mechanisms of conduction, convection and radiation.

- **Sensible heat**: Heat that increases the temperature of air. It is an expression of the molecular excitation of a given mass of solid, liquid, or gas.

- **Latent heat**: Heat that is present in increased moisture of air. It changes the matter from solid to liquid or from liquid to gas. Heat that is required to change solid to liquid is called latent heat of fusion, and that which is required to change liquid to gas is called latent heat of vaporization.

- **Enthalpy**: The sum of sensible and latent heat of a substance; e.g., the air in our environment is actually a mixture air and water vapor. If the enthalpy of air is known, and the enthalpy of desired comfort condition is also known, the difference between them is the enthalpy that must be added (by heating or humidification) or removed (by cooling or dehumidification).

- **Units**: The common measure of quantity of heat energy is British thermal unit (BTU). It is the heat energy required to raise one pound of water one degree Fahrenheit. The rate of heat flow in this unit is BTUH. The unit is Joule in the International System. It is the heat required to raise one liter of water one degree Celsius. The rate of heat flow in this unit is Joules/sec or Watts (W). One watt per hour is equivalent to 3.412 BTU per hour. (1 Joule = 0.0009478 BTU = 1 Watt; 1 Watt-Hour = 0.0009478*60*60 = 3.412 BTUH.)

- **Temperature**: A measure of the degree of heat intensity. The temperature difference between two points indicates a potential for heat to move from the warmer point to the colder point. The temperature unit in the English system is Fahrenheit, and the temperature unit in the International System is Celsius.

- **Dry-bulb temperature (DB)**: The dry-bulb temperature is the temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture. More specifically, it is a measure of the intensity of the kinetic energy of the molecules in the air. It is one of "the most important climate variables for human comfort and for building energy efficiency."

- **Wet-bulb temperature (WB)**: The temperature registered by a thermometer whose bulb is covered by a wetted wick and exposed to a current of rapidly moving air. It is the temperature air would have if part of its energy were used to evaporate the amount of water it would absorb to become fully saturated.

- **Dew point temperature**: The temperature at which condensation begins when the air is cooled.

Variables affecting physical comfort

Human beings are essentially constant-temperature creatures with a normal internal body temperature of 98.6°F. Heat is produced in the body as result of metabolic activity. If the internal temperature rises or falls beyond its normal range, mental and physical operation is jeopardized or affected, and if the temperature deviation is extreme, then serious physiological disorders or even death can result.

The physiological interpretation of comfort is the achievement of thermal equilibrium at our normal body temperature with the minimum amount of bodily regulation.

The factors that affect physical comfort are the following:

- **Metabolic rate** is the rate at which food consumed is converted into electromechanical energy to maintain physical functions. Heat is produced in the body as a result of metabolic activity. Its production can be controlled to a certain extent by controlling metabolism or oxidation. Metabolic rate can also be defined as the rate of body heat production under conditions that minimize extra requirements for energy. Given a set of metabolic rate, however, the body must reject heat at the proper rate in order to maintain normal body temperature. Metabolic rate is proportional to body weight, and is also dependent upon activity level, body surface area, health, sex, age, amount of clothing, and surrounding thermal and atmospheric conditions. Metabolic rate is measured in **Met** units. For an average person, one Met unit corresponds approximately to 360 BTU per hour. A Met is the average amount of heat produced by a sedentary person, and any metabolic rate can be expressed in multiples of this standard unit (e.g., office work = 1 Met).

  - The unit of the electromechanical energy produced due to metabolism is the Calorie. A Calorie is defined as the amount of heat required to raise the temperature of 1 gram of water by 1 degree Celsius at 1 atmosphere pressure. This measure is typically used for food values. 1 Calorie = 4.1868 Joules.

- **Conduction** is the spontaneous transfer of thermal energy through matter, from a region of higher temperature to a region of lower temperature, and acts to equalize temperature differences. It is also described as the heat energy transferred from one material to another by direct contact.

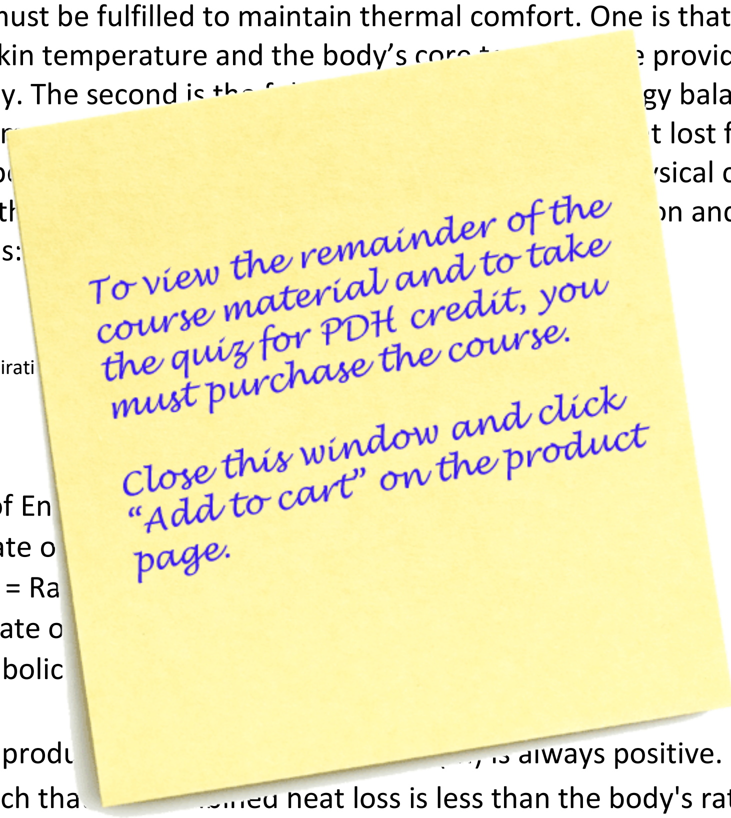
- **Convection** is usually the dominant form of heat transfer in liquids and gases. Convection is the circulation of a fluid or gas/air caused by temperature difference. Commonly, *an increase in temperature produces a reduction in density*. Hence, when water is heated on a stove, hot water from the bottom of the pan rises, displacing the colder, more dense liquid, which falls. Mixing and conduction result eventually in a nearly homogeneous density and even temperature. In HVAC applications, convection becomes increasingly effective at dissipating heat as air temperature decreases and air movement increases. This is because the faster the rate of air movement, the larger the temperature difference between the body and surrounding air, and the larger the body surface area, the greater the rate of transfer.

- **Evaporation** is exclusively a cooling mechanism. Evaporative losses become a predominant factor when ambient temperatures are very high. When the surrounding temperature is about 70°F, most people lose sensible heat at a rate that makes them feel comfortable. If the surrounding temperature rises to skin temperature, the sensible heat loss drops to zero. If the ambient temperature continues to rise, the body gains heat from the environment, and the only way it can lose heat is by increasing evaporation. The moisture carrying potential of the air determines the rate of evaporation and evaporative heat loss. It is dependent on the relative humidity (RH) of surrounding air and the velocity of air motion.

- **Radiation** is the only form of heat transfer that can occur in the absence of any form of medium; thus, it is the only means of heat transfer through a vacuum. Thermal radiation is a direct result of the movements of atoms and molecules in a material. Radiation affects two bodies when they are in direct line of sight of each other. The rate of radiant transfer depends on temperature differential, the thermal absorption capacity of surfaces, and the distance between the surfaces. The body gains or loses heat by radiation according to the difference between the body surface and the mean radiant temperature (MRT) of the surrounding surfaces.

Predictions of Thermal Comfort

Two conditions must be fulfilled to maintain thermal comfort. One is that the actual combination of skin temperature and the body's core t[…] provide a sensation of thermal neutrality. The second is th[…]gy balance: the heat produced by the r[…]t lost from the body. Excess body heat must b[…]ysical comfort. Mathematically, th[…]on and all its other heat gains and losses is:



$S = - Q_{skin} – Q_{respirati}$[…]

Where:

- S = Rate of En[…]
- Q_{skin} = Rate o[…]
- $Q_{respiration}$ = Ra[…]
- W_{mech} = Rate o[…]
- M = Metabolic[…]

The body always produ[…] is always positive. If environmental conditions are such tha[…]ined heat loss is less than the body's rate of heat production, then excess heat must be stored in body tissue. However, the body heat storage (S) is always small because it has a very limited thermal capacity. Therefore, when the interior temperature gets warmer, the body reacts to correct the situation by increasing blood flow to the skin surface and increasing perspiration. As a result, body heat loss is increased, thereby maintaining the desired body temperature. Shivering occurs when heat loss is greater than heat production.