

KINZEY  
and  
SHARP

Environmental  
Technologies in  
ARCHITECTURE

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## Preface

*Architecture has evolved from a concept of simple shelter into a complex environmental control system. Science and engineering have developed equipment and techniques which make possible light, heat, sanitation, and noise management, close to the norms required for the balanced functioning of the human being. Far-sighted provision for the control and distribution of electrical power is essential, not only for the immediate operation of necessities but for the inevitable expansion in future techniques and concepts. The building itself, while only one part of the environmental control, must provide accommodation for the multitudinous mechanical and electrical facilities required.*

*It is the authors' premise that the correlation of the building with its complex equipment must provide a total surround that will meet the physiological and psychological needs of the occupants. A building should fit the whole man, not force man to an unnatural conformity with a building.*

*In recent years, architectural schools have usually educated their students in the mechanical and electrical elements of buildings through diluted courses offered by the respective engineering departments. This approach stresses equipment without a conscious link with architecture and fundamental human requirements. The positive total approach taken by the authors of this text is to consider the provision of heat, light, sound control, sanitation, and electric power in terms of the building and the equipment working together.*

*This integration requires the closest cooperation and coordination between the architect and his engineering consultants. This must begin at the very outset of the planning and continue until the drawings and specifications are completed. The architect need not perform the more detailed engineering studies. He must, however, be conversant with the common engineering language and concepts in order to be effective in his role of coordinator of the fine art of architecture and the engineering sciences.*

*This book is written for students in architecture and other areas of the building industry who have a background which includes the equivalent of*

*high-school physics and algebra. Engineering design principles are given. The extent to which they are pursued will vary in different schools according to the stated objectives of the curriculum. Some of the engineering aspects can be omitted without jeopardizing the effectiveness of the text and any material not covered in the classroom will be valuable to the student for future study and reference. References are given at the end of each chapter as guides to study beyond the scope of this book.*

*Recognition is gratefully given to all those who so willingly contributed materials and ideas for the text. Illustrative material furnished by industry, professional societies, and others is credited where it is introduced. Original line drawings were made by C. J. Sharitz, assisted by J. F. Eberman, former students of Architectural Engineering at the Virginia Polytechnic Institute. To our wives, we owe a full measure of thanks for the mass of typing required for producing the manuscript and the correspondence attendant to it.*

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*From the Heating Ventilating Air Conditioning Guide 1958: Figure 2-6.*

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PART ONE

# Thermal and Atmospheric Environmental Control

*Architecture is usually defined as shelter. This definition implies, among other things, the maintenance of thermal and atmospheric conditions in enclosed spaces which differ from those existing concurrently outdoors. Control of these conditions is realized by the nature of the enclosed envelope as conceived by the architect and the equipment serving it as devised by the engineer. These professionals arrive at the best solution to the control problem through the close coordination of their efforts.*

*Thermal and atmospheric conditions in an enclosed space are maintained for one of two reasons. Usually, we wish to maintain a situation conducive to human comfort, but manufacturing processes, such as for paper, tobacco, and synthetic fibers, require close control of the thermal and atmospheric nature of the environment. The conditions required for manufacturing may or may not coincide with those considered appropriate for human comfort, but since the consideration of human comfort far exceeds that of environments for industrial needs, our discussion here will be devoted to the problem of human comfort.*

# 1

## Heat and Moisture in the Atmosphere and Human Comfort

### 1-1 TERMINOLOGY

For this discussion of human comfort and thermal and atmospheric surroundings, we must define the technical terminology necessary for the clarity which engineering and scientific subjects demand. Also, we must examine the thermodynamic behavior of air-vapor mixtures; control of an atmospheric environment for comfort conditions involves changes of heat and moisture content in the air. Then, we can proceed with the subject of human comfort and the means of maintaining it in controlled climates. Many terms and principles are easier to understand if they are introduced at the point in the discussion where they are applicable. Here we will define only general terms.

*Air conditioning*        The treatment of air so that its temperature, humidity, cleanliness, and distribution are maintained concurrently in accord with the requirements of the conditioned space. When the requirements are concerned with the maintenance of human comfort, the process is called *comfort air conditioning*.

*Air* Often reference to air requires qualification. *Dry air* is air which contains no water vapor. *Saturated air* is a mixture of dry air and saturated water vapor both of which have the same dry-bulb temperature; that is, the air contains all the water vapor it can hold. *Standard air* is air which has a density of 0.075 lb per cu ft and an absolute viscosity of  $1.22 \times 10^{-5}$  lb mass per (ft)(sec). Practically speaking, this is air at 70° F and 29.92 in. Hg barometer. Changes in temperature and pressure cause corresponding changes in volume but not in weights of air handled. Volumetric changes are significant in air conditioning problems.

*British thermal unit (Btu)* Commonly the measure of quantity of heat energy is said to be that heat energy required to raise one pound of water one degree Fahrenheit. This is not a precise definition but is adequate for our purpose. We are usually concerned with rate of flow of heat for which the customary units are Btu per hr.

*Condensate* A liquid formed by condensation of vapor. When steam gives up its heat at a heat transfer surface, condensate is formed which is returned to the boiler where it again becomes steam. Water deposited from air on cooling coils is condensate. This dehumidifying process requires a drip pan and drain under the coil to remove the condensate.

*Conductance; conductivity* Thermally, conductance is the time rate of heat flow through the unit area of a body per unit of temperature difference. The customary unit of measurement is Btu per hr per sq ft per °F and the symbol is *C*. Conductivity is similar except that it is applied to homogeneous materials and the unit is Btu per hr per sq ft per °F per inch thickness. The symbol is *k*. The terms *resistance* and *resistivity* are reciprocals of these terms and the symbols are *R* and *r* respectively.

*Convection* A means of transmitting heat energy between a surface and a fluid moving over it. When the fluid moves as a result of the differences in densities which accompany temperature changes and the action of the force of gravity, the heat transfer is called *natural convection*. Mechanical movement of the fluid causes *forced convection*. A device having a heat transfer surface designed to transfer heat to a fluid largely by convection is known as a *convector*.

*Enthalpy* A term meaning *total heat*. Often the heat content of air and water vapor is stated in terms of Btu per lb using 0° F as the base line representing no heat. If the heat content or enthalpy of air is known before and after treatment, the difference of the figures gives the change in enthalpy or the heat load required to accomplish the heating or cooling and humidification or dehumidification of the air. Both sensible and latent heat are included.

*Heat* A form of energy which flows from one point to another which are at different temperatures and which can communicate with one another. When a substance changes temperature due to a change in heat content, the heat causing the change is called *sensible heat*. Heat which changes the state of matter from solid to liquid or liquid to gas on addition of the heat or in reverse order when heat is extracted is called *latent heat*. *Specific heat* is the quantity of heat which changes a unit mass of a substance one degree of temperature. The English units are Btu per lb per °F.

*Heating medium* A substance used to carry heat from a source to a heat disseminator. Steam, water, and air are the media in common use.

*Heat transmission coefficient* A unit which is the measure of heat transmissibility of a composite assembly of building materials making up a wall, floor, etc., including the air films, if any, on either surface. The thermal conductances of each of the components of construction are taken into account. The units are Btu per hr per sq ft per °F, and the symbol is *U*.

*Humidity* Water vapor in a given space. If the density of water vapor in a unit volume of air is stated, the term is called *absolute humidity*. The units are lb (of water) per cu ft (of dry air). The weight of water vapor per unit weight of dry air given in lb per lb is called the *humidity ratio* or *specific humidity*. The weight of water present in a given weight of dry air divided by the maximum weight of water the air can hold at the same temperature without causing condensation, that is at saturation, is known as the *degree of saturation*, and this ratio multiplied by 100 is the *percentage humidity*. This percentage is a measure of the dryness of air. Low percentages indicate relative dryness, and high percentages show that the air is quite moist. Percentage humidity is often mistakenly called relative humidity. *Relative humidity* is the ratio of the actual vapor pressure of the air-vapor mixture to the pressure of saturated water vapor at the same dry-bulb temperature times 100. Percentage and relative humidity are close to each other numerically but are not identical.

*Inch of water* Pressures in heating, ventilating, and air conditioning problems are frequently expressed in terms of the heights of water columns they will support. A column of water at 62° F and 1 in. high exerts at its bottom a pressure of 0.03609 lb per sq in. or 2.309 ft of water exerts one lb per sq in. Instead of lb per sq in. the units for pressure are given in inches, milinches (thousandths of an inch), or in feet of water. Sometimes the designation is inches W.G. (water gauge).

*Psychrometry* That branch of physics concerned with the study of atmospheric conditions including especially the mixture of air and moisture.

An instrument used to measure the humidity of the atmosphere is called a *psychrometer*, and the graphical representation of the thermodynamic behavior of air-vapor mixtures is known as a *psychrometric chart*.

**Radiation** The transmission of heat energy by electromagnetic waves. When a body absorbs radiant energy, its temperature increases.

**Temperature** A measure of heat intensity. Temperature differences between two points indicate the ability of heat to move from the warmer to the colder point. The Fahrenheit scale is used in our consideration of thermal environmental control problems.

The *dry-bulb temperature* of a gas or mixture of gases is the temperature taken with a thermometer whose bulb is not in contact with water and is not affected by radiation of heat to or from it. The usual thermometer on the wall registers the dry-bulb temperature of the air.

If a thermometer bulb is moistened, any evaporation of water extracts sensible heat from the air surrounding the bulb. The heat vaporizes the water and becomes latent heat. The exchange of sensible for latent heat in the air does not change the total heat content during the process of saturating the air around the bulb. This method of humidifying air without changing its total heat content is known as *adiabatic saturation*. When sensible heat is extracted from air, its temperature is lowered. Hence, a thermometer with a wet bulb indicates a temperature lower than a dry-bulb thermometer, for the evaporating water saturates the air, taking all the sensible heat from it that it can. The drier the air, the greater will be the exchange of latent for sensible heat and the wet-bulb temperature will be correspondingly lower. The *wet-bulb temperature* is, then, a means of determining the humidity of air. When the dry- and wet-bulb temperatures coincide, the air already has all the water vapor it can hold, therefore, no evaporation can take place and the percentage humidity is 100%. From the dry- and wet-bulb temperatures of any sample of air one can ascertain the humidity. The larger the temperature difference, the lower is the humidity.

Air under constant pressure and at a given specific humidity may be cooled, in which case the air-water vapor mixture becomes relatively more humid as the temperature decreases. Finally, a temperature is reached at which the given water content saturates the air. That is, the quantity of water vapor present is all that the air can hold at the temperature. Any further lowering of temperature causes condensation of some of the water vapor. The temperature at which condensation begins is known as the *dew-point temperature*.

Temperatures of surfaces surrounding an enclosed space and their relation to the temperature of a body within the space determine the rate and direction of heat flow between the body and the surrounding surfaces. The comfort of a person in a space is affected by the radiant exchange of heat between occupant and the surfaces. Therefore, we find it useful to know the radiant surface